TRANSACTIONS

OF THE

ROYAL SOCIETY OF EDINBURGH.

VOL. XXIV. PART II.—FOR THE SESSION 1865–66.

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TRANSACTIONS

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VOL. XXIV. PART II.—FOR THE SESSION 1865-66.

XX.—*On the Influence of the Doubly Refracting Force of Calcareous Spar on the Polarisation, the Intensity, and the Colour of the Light which it Reflects.*

By Sir DAVID BREWSTER, K.H., F.R.S.

(Read 15th February 1864.)

It was the opinion of MALUS, and adopted by ARAGO, BIOT, and other philosophers, that the surfaces of regularly crystallised bodies acted upon light in the very same manner as the surfaces of ordinary bodies, whether solid or fluid; or, in other words, that the reflecting forces extended beyond the limits of the forces that produced double refraction and polarisation. Having been led to question this opinion, I undertook an extensive series of experiments on crystalline reflexion, as exhibited in calcareous spar, a crystal peculiarly fitted for this purpose, from its perfect transparency and great double refraction; and I published the results of these experiments in the Philosophical Transactions for 1819.

In these experiments, the peculiar action of crystalline surfaces which I had expected was placed beyond a doubt. The angle of complete polarisation on the surface of the primitive rhomb was found to vary with the inclination of the plane of reflexion to the principal section of the crystal; and with different surfaces the variation of that angle depended on the inclination of the surface to the axis of the rhomb.

As the doubly refracting force thus modified the polarising angle produced by superficial reflexion, it became probable that the polarised ray might suffer some change from the same cause; but, after the most careful observation, I could not discover the slightest indication of such an effect. Conceiving, however, that the change which I expected might be masked by the powerful action of the ordinary reflecting force, I thought of reducing it till it was overpowered by the doubly refracting force. With this view, I introduced a film of oil of cassia between the larger surface of a rectangular prism of plate glass and the surface of the spar, and by inclining the prism at a small angle, as in the LITHOSCOPE, I was able to separate the image of the sun, or any other light formed by the common surface of the prism and the oil, from the image formed by the common surface of the spar and the oil, and to examine the properties of the last of these images.

In this way I found that the ordinary reflecting force of the spar was nearly reduced to nothing, and was almost entirely under the dominion of the force which emanated from the crystal. Light incident on the crystalline surface was no longer polarised in the plane of reflexion, but in planes inclined to the principal section of the crystal, the rotation or deviation of the plane increasing with the angle which the plane of reflexion formed with the principal section, and was so related to the angle which the incident ray formed with the axis of the crystal, that the Sine of half the rotation, or deviation, was equal to the square root of the Sine of the incident ray to the axis.

The bearing of these results, as published in the memoir already referred to, upon the theory of Light, directed the attention of mathematicians to this subject, and I was thus induced to resume the inquiry, by investigating the action of surfaces variously inclined to the axis of calcareous spar,—to study the effect of fluids of different refractive powers, in reducing the action of the reflecting force, and to ascertain the influence of the surfaces thus modified upon light polarised in planes differently inclined to the principal section of the crystal.

Some of the results thus obtained were communicated at different times to the British Association, and were found by the late Professor MACCULLAGH of Trinity College, Dublin, to be deducible from the Undulatory Theory; but other results, in which the phenomena were asymetrical with respect to the principal section of the crystal were less accordant with theory. Professor MACCULLAGH was therefore desirous to observe the phenomena himself; and having resolved to have an apparatus constructed more complex and perfect than the one I used, I willingly left the subject in the hands of my distinguished friend. What experiments he made, or whether he made any, before the sad and sudden close of his life in 1847, I have not learned. The subject has therefore again come into my hands; and having been encouraged by Professor STOKES of Cambridge to publish my experiments, as having an important bearing on the theory of light, I now submit them, incomplete and imperfect as they are, to the consideration of the Society.

The experiments which I published in 1819 were made on the cleavage planes of the primitive rhomb of calcareous spar, but those which I am about to describe were made on artificial faces, carefully prepared for me by the late Mr WILLIAM NICOL, the ingenious inventor of the polarising prism which bears his name.

I could have wished to repeat some of these experiments with a better apparatus, and with freshly polished surfaces of calcareous spar, but the sharp vision and the sensitive retina of early or middle life are necessary for the observation of delicate and almost evanescent phenomena.

In the following Table I have given the observed polarising angles of the surfaces employed, and of their inclination to the axis of the rhomb:—

	Inclination to Axis.	Observed Polarising Angle.*
A	0°	54° 3′
A1	4 40′	54 16
D	22 30	55 22
B	45 23	57 12
B1	50 51	...
B2	57 31	...
E	67 30	59 16
E1	84 30	59 38
C	90 0	59 59

B. SURFACE OF RHOMB, INCLINATION TO AXIS 45° 23′.

1. *With Oil of Cassia, on an Artificial Face.*

AZIMUTH 90°. Obtuse angle to the right.

Light polarised 0° and 90°. E′ and O′† vanish simultaneously $42\frac{3}{4}°$ to the left of the plane of incidence, E′ being *reddish* and O′ *yellowish*.

Light polarised + 45° and — 45°. E′ is polarised $45\frac{1}{2}°$ to the left. O′ vanishes, but a little *blue* light is left, which disappears along with E and O. O′ vanished more completely by turning the rhomb that gave the images E, O, 9° or 10° farther, from 45° to 55°.

AZIMUTH 270°. Obtuse angle to left.

Light polarised 0° and 90°. E′ and O′ vanish simultaneously $33\frac{1}{2}°$ to the right of the plane of incidence. A little *blue* light remains in E′ and O′ at the point of evanescence.

Light polarised + 45° — 45° O′ is polarised 35° to the right. E′ vanished completely.

2. *With Oil of Cassia, on a Natural Face of Cleavage.*

AZIMUTH 90°. Light polarised 0° and 90°. E′ and O′ vanish simultaneously $47\frac{1}{2}°$ to the left.

Light polarised + 45° — 45°. E′ is polarised 46° to the left. O′ is scarcely visible.

AZIMUTH 270°. Light polarised 0° and 90°. E′ and O′ vanish simultaneously $42\frac{1}{2}°$ to the right.

Light polarised + 45° — 45°. O′ is polarised $44\frac{1}{2}°$ to the right. E′ is nearly invisible.

Common light is polarised 44° to the right.

N.B.—The evanescence is not complete either on the glass or on the spar surface; but more complete on the natural than on the artificial face of the spar.

AZIMUTH 38°. Obtuse angle to right. In common sun's light, E′ and O′ vanish simultaneously at 45° of incidence, and in a plane $82\frac{1}{2}°$ to the right of the plane

* In the plane of the principal section. See Phil. Trans., 1819, p. 158.

† E′ and O′ are the extraordinary and ordinary images from the spar, and E and O the same from the prism surface.

of incidence. The vanishing image is at its *minimum* when crossed half with *blue* and half with *red* light.

Light polarised $+45°-45°$. E′ and O′ polarised simultaneously $82°\frac{1}{2}$ to the plane of incidence. Both have the same intensity, and are crossed at their minimum with *red* and *blue* light.

Light polarised 0° and 90°. Although E does not suffer reflexion from the glass surface, yet E′ is visible, and vanishes, along with O′, $82\frac{1}{2}°$ to the right of the plane of incidence.

Azimuth 218°, Obtuse angle to the Left. Common sun's light is completely polarised 8° to the right of the plane of incidence. The evanescence is complete at the polarising angle of O, but not at greater angles.

Light polarised 0° and 90°. E′ and O′ are both polarised 8° to the right. E′ is bright *yellow* and O′ bright *pink*.

Light polarised $+46°-45°$. E′ and O′ are polarised 8° to the right, E′ being *yellow* and O′ *blue*.

Azimuth 15° to the left. Light polarised 0° and 90°. E′ and O′ vanish together, and O′ is polarised about 40° to the right.

Light polarised $+45°-45°$. Obtuse angle from the eye E′ and O′ are polarised 55° to the right.

Azimuth 45°. Light polarised $+45°-45°$. E′ and O′ vanish completely at polarising angle 92° to the right. The deviation is increased by increasing the incidence.

On the Intensity of the Reflected Pencil.

Common Light, Azimuth 0° and 180°. The spar and oil image S is equal to about $\frac{1}{3}$ of the prism image P.

Azimuth 45° and 215°. $S=\frac{2}{3}$ P.

Azimuth 90° and 270°. S = P, P a little brighter.

Light polarised $+45°-45°$.

Azimuth 0° and 180°. O′ gradually diminishes and vanishes at 90°, while E′ increases and is a maximum at 9°.

Azimuth 90° and 270°. E′ is a maximum and nearly equal to O′, which almost vanishes.

Beyond 90° and 270°, O′ gradually increases while E′ diminishes, and they become equal at 180°.

Light polarised 0° and 90°. Azimuth 0° and 180°. O′ almost vanishes, but E′ is bright, though only equal to $\frac{1}{3}$ P. O′ increases gradually to azimuth 90°, where it is equal to O.

Azimuth 90° and 270°. E′ = O′, both pretty bright, but less so than P.

Azimuth 123°. E′ vanishes. O′ a little less than P.

Azimuth 180°. O′ vanishes. $E'=\frac{1}{3}$ P.

B *With Oil of Anise Seeds.*

AZIMUTH 0° and 180°. E′ and O′ vanish together, E′ at all angles less than 45°. O and a great part of E, viz. the *blue* light and more is polarised at angles above 45°, a small portion of *red* light remaining. O = E, O *bluish* and E *yellowish*.

AZIMUTH 90° and 270°. Change of polarisation 94° to left. Maximum polarising angle for E′ at angles much less than 45°, polarisation nearly complete. No appearance of polarisation at great incidences. O′ = E′.

AZIMUTH 39° and 321°. Change of polarisation 50° to left. The maximum polarising angles commence at the angle of polarisation for O, and the polarisation is complete at angles both above and below 45°.

AZIMUTH 219°. Change of polarisation 0°, O′ and E′ vanishing at the same time at about 45°. Above 45°, E′ is nearly wholly polarised 15° to the right, while below 45°, it is polarised 0°, 5°, 10°, &c. to the left as the incidence diminishes.

With sunlight complete polarisation took place much lower than 45°, and *blue* light was less in this light.

B. *With Oil of Sassafras.*

AZIMUTH 0° and 180°. No change in the plane of polarisation. O′ is bluish and = 4 to 5 E′.

AZIMUTH 39°. Change of polarisation about 30°.

AZIMUTH 219°. Change of polarisation 0°.

AZIMUTH about 60°. Change of polarisation 45°, the polarisation increasing at great incidences.

AZIMUTH about 70°. Change of polarisation about 50°. Maximum polarisation about 48° of incidence.

AZIMUTH 90°. No light seems to be polarised at or above 45°.

AZIMUTH about 240°. Change of polarisation from 15° at great incidences to about 25° at small incidences. Light polarised in plane of reflexion is treated nearly as common light, but light polarised 90° out of that plane has a change of polarisation a few degrees greater, owing to its being incident at a less angle; the one image from the polarising rhomb being higher than the other.

B. *With Castor Oil.*

AZIMUTH 0° and 180. O′ and E′ completely polarised without any change of plane.

AZIMUTH 39°. Change of polarisation about 10° to left.

AZIMUTH 90°. Change about 20° to left at moderate incidences.

AZIMUTH 141°. Change 0°. Polarisation complete.

AZIMUTH 219°. Change 0°. Polarisation complete.

AZIMUTH 270°. Change about 10° to right at considerable incidences.
AZIMUTH 321°. Change 10° to right, and polarisation complete.

B. *Oil of Cajeput.*

AZIMUTH 39°. Change about 5° to left, and polarisation complete.
AZIMUTH 90°. Change 7° to left at moderate incidences.
AZIMUTH 141°. Change 0°. Polarisation complete.
AZIMUTH 219°. Change 0°. Polarisation complete.
AZIMUTH 270°. Change 5° to right at considerable incidences.
AZIMUTH 321°. Change 5° to right. Polarisation complete.

B. *With Olive Oil.*

AZIMUTH 39°. Change about 5° to left.
AZIMUTH 90°. Change about 100° to left.
AZIMUTH 141°. Change 0°. Polarisation complete.
AZIMUTH 219°. Change 0°. Polarisation complete.
AZIMUTH 270°, Change 8° to right.
AZIMUTH 321°. Change 5° to right. Polarisation complete.

B. *With Alcohol highly rectified.*

AZIMUTH 39°. Change about 1° or 2° to left. The two images vanish at different incidences, S at greater than P.

AZIMUTH 90°. Change about 1° or 2° to left, spar pencil at angle greater than prism pencil.

AZIMUTH 141°. Change 0°.
AZIMUTH 270°. Change about 1° or 2° to left.
AZIMUTH 280°. Change 0°. Polarisation complete.
AZIMUTH 321°. Change at 1° or 2° to right.

A. THE FACE PARALLEL TO THE AXIS.

With Oil of Cassia.

The following observations were made with a plate of glass placed on the surface of the spar, the plate being inclined about 5° in the Azimuth 0° parallel to the axis.

Azimuths.	Change of Polarisation.	Azimuths.	Change of Polarisation.
0°	93° *	50°	47°
10	85	60	37
20	80	67½	33
22½	74	70	32
30	55	80	20
40	59	90	0
45	55		

* The change was 90° at the polarising angle of the spar and oil surface.

These observations were made at angles of incidence considerably greater than 45°, the polarising angle.

The following experiments were made with polarised light.

Inclination of Plane of Polarisation to Plane of Incidence.	Inclination of New Plane to Plane of Incidence.
0°	0°
22½	30
45	67½
67½	79
90	90

When E′ was polarised 90° and O′ 0°, O′ was nearly thrice as faint as E′, and much *redder*.

When the spar and oil image vanishes, *red* light is seen on one side, and *blue* on the other side of the vanishing point, as in elliptical polarisation, the rotation being different for different colours.

The following experiments were made with an equilateral prism of glass.

In AZIMUTH 0° and 180°. Light polarised + 45° — 45° is polarised + 67°—67°, the change of polarisation being 22°.

AZIMUTH about 9°. Light polarised 0° and 90°. E′ is polarised 87° to the left, and O′ and O vanish together. Common light is polarised 87° to left.

Light + 45°—45°. E′ is polarised 59½° to left, and O′ 71½° to right. E′ and O′ are equally bright.

AZIMUTH about 17°. Light + 45°—45°. E′ is polarised 27½° to left, and O′ 80½° to right. E′ is very faint and *red*.

AZIMUTH about 40°. Light + 45°—45°. Both O′ and E′ polarised 25° to left. O′ is brighter than E′, which is faint and *bluish*.

AZIMUTH ABOUT 60°. Light + 45 — 45°. O′ and E′ vanish together a few degrees to the left.

AZIMUTH 90°. Light + 45°—45°, and light 0° and 90°, are treated exactly as by common surfaces; the prism and spar images undergoing the same changes.

As the plane of light polarised + °45 — 45°, becomes light + 0°—0°, or is all polarised in the plane of reflexion, as the azimuths change from 0° to 90°, the inclination of their planes must diminish from 90° to 0°, or from 135° to 0°; that is, from + 67½° — 67½°, to + 0° — °0.

From the observations with common light, it appears that at angles of incidence considerably above 45°, it is polarised a few degrees beyond the azimuth of 90°, and we have no doubt, that at 45°, it is polarised in that azimuth. Hence, it follows, that the change of polarisation is equal to the complement of the azimuth, or 90 — A.

A. *With Oil of Anise Seeds.*

AZIMUTH 0° and 180°. Scarcely any effect is produced upon common light at any incidence! The spar pencil is brighter than the prism pencil, and *yellow*.

AZIMUTH between 0° and 90°, and 0° and 270°, the pencil is almost wholly polarised at great incidences, and about 90° to the left.

AZIMUTH 0° and 180°. Light $+45° - 45°$. E′ was polarised $30\frac{1}{2}°$ to left, and 36° to right. Instead of widening the planes of E′ and O′ into $+67\frac{1}{2} - 67\frac{1}{2}$, the anise seeds oil has brought them nearer into $+30\frac{1}{2}° - 36°$. Conceiving, therefore, that an oil of intermediate refractive power might produce little or no change upon the light $+45° - 45°$, I mixed 2 drops of oil of cassia with 1 drop of oil of anise, and obtained the following results.

A. *Oil of Cassia and Oil of Anise Seeds.*

AZIMUTH 0° and 180°. Light $+45° - 45°$. E′ is polarised 44° to the *left*, and 0° 44° to the right; that is, almost no change is produced.

With common light there is not a trace of polarisation, and yet reflexion from a transparent surface!

Light 0° and 90°. O′ vanishes with prism image, and A′ polarised about 90°.

AZIMUTH 90° and 270°. With common light, the spar and prism image vanish together.

Between AZIMUTH 0° and 90°. With common light, the polarisation increases to about 45° of azimuth, when it is complete, and then gradually returns into common light at 90°.

C. *Face perpendicular to Axis.*

On the natural surface of the *Chaux Carbonatè Basé*.

Oil of Cassia.

With common light the spar image E is polarised 90° out of the plane of reflexion, and is then *orange*, showing that the light polarised 90° is *blue*. It becomes whiter at great incidences, and redder at small ones. The prism image O is $=2E$ at 45°. At greater incidences E increases faster than O, and becomes nearly equal to it. At small incidences, E decreases much faster than O, so that it follows a different law of reflexion.

At the greatest incidences which the prism allows, the spar pencil is completely polarised.

Light polarised $+45° - 45°$. E′ is polarised 67° to right, and O′ 67° to left.

Light polarised 0° and 90°. O′ vanishes with O, and E is polarised 90° to left.

Oil of Anise Seeds.

In all azimuths about $\frac{1}{2}$ or $\frac{2}{3}$ of E is polarised 90° out of the plane of reflexion

at great incidences. At the polarising angle, the light polarised 90° is scarcely perceptible. The residual light is *reddish*, and it is obviously *blue* light that is polarised 90°.

Light polarised +45—45°, becomes polarised +36—36.

With Alcohol.

The prism image O is completely polarised, and the spar image E equally so in the same plane, but at an incidence 3° or 4° greater.

With oil of sassafras, cassada balsam and water, there is no change in the plane of polarisation.

D. *Face inclined 22½° to Axis.*

AZIMUTH 0° and 180°. In common light, the change of polarisation is 90° to the left. It decreases to 20° in azimuth 90°, becomes 0° in azimuth 113°, and in AZIMUTH 180°, it again becomes 90°, decreasing to 0° in azimuth 247°, becoming 20 in azimuth in 270°, and increasing to 90 in azimuth 360°.

AZIMUTH 0° and 180°. Light + 45 —43°. E′ is polarised 45⅓ to left and O′ 62⅔° to right.

AZIMUTH ABOUT 15°. Light +45°—45°. O′ is polarised 85½° to left, E vanishing with O and E the prism images. When O′ vanishes E′ has reappeared, and is *red*.

AZIMUTH 38°. Light +55° — 45°. E is polarised 50° to the right, and O′ 77½° to the left.

AZIMUTH 20°. E′ is polarised 17° to left, and O′ 83° to right.

AZIMUTH 113. Light +45°—45′. No change, E′ and O′ being both polarised in the plane of reflexion. E′ nearly vanishes when O′ vanishes; but by increasing the incidence it vanishes completely, showing the usual red and blue at the point of evanescence.

AZIMUTH 135°. Light +45°—45°. E′ is polarised 22° to right, O′=O and vanishing with O.

AZIMUTH 142°. Light +45°— 45°. E is polarised 31′ to the right, O′ vanishing with O.

AZIMUTH 160°. Light +45°—45°. E′ is polarised 66° to right, and O′ 22° to right.

AZIMUTH 218°. Light +45°—45°. E′ is polarised 11° to left, and O′ 77° to left.

AZIMUTH 90°. Light +45°—45°. E′ and O′ are both polarised 28° to the left.

AZIMUTH 270°. Light +45°=45°. E′ and O′ polarised 18′ to right.

AZIMUTH 315°. Light +45°—45°. E′ is polarised 59° to right, and O′ 69° to the left.

AZIMUTH 322°. Light +45°—45°. E′ polarised 61° to right, and O′ 83° to right.

AZIMUTH 180°. Light +45° — 45°. E′ is polarised 50½° to left, and O′ 58° to right.

AZIMUTH 0°. Light 0° and 90°. E′ is polarised 90° out of the plane of reflexion, O′ vanishing with O.

AZIMUTH 180°. Light 0° and 90°. E′ is polarised to the left, about 86°, O′ vanishing with O.

AZIMUTH 270°. Light 0° and 90°. E′ and O′ polarised 21° to the right.

AZIMUTH less than 270°. Light 0° and 90°. E′ and O′ polarised 8° to the right.

With Oil of Anise Seeds.

AZIMUTH 0° and 180°. When the prism pencil with common light vanishes, the spar pencil is very bright, and a great deal of light, namely, reddish light is polarised in the plane of reflexion.

AZIMUTH 90° and 270°. The spar pencil is completely polarised about 7° to the left.

In the azimuth, between 90° and 180° perpendicular to the edge beside the obtuse angle, change of polarisation varies from 45° of incidence where it is 0°, up to great incidences, where it is about 45° or 50° to the left, the pencil being there completely polarised. Between azimuths 270° and 360°, the change varies from 125° to 100° at great incidences, but the pencil is nowhere completely polarised.

With Alcohol.

At AZIMUTHS 0° and 180°, there is no change of polarisation, but the spar image is polarised at a much less angle of incidence than the prism image, whereas at azimuth 90°, they are polarised at the same incidence.

E. *Face inclined 67° 30′ to the Axis.*

In AZIMUTH 0° and 180°, the change of polarisation is 90°, the polarisation being more complete, by considerably increasing the incidence.

The change of polarisation increases from azimuth 0° to azimuth 90°, diminishes from 90° to 270°, and increases from 270° to 369°.

In AZIMUTH 0° and 180°. At the polarising angle only half the pencil is polarised 90° out of the plane of reflexion, the other half appearing to be polarised in another plane.

AZIMUTH 0°. Light +45° — 45°. E′ is polarised 45° to the right, and O′ 61° to the left.

AZIMUTH 9°. Light + 45° = 45°. E′ is polarised 67° to the right, and O′ 55° to the left.

AZIMUTH about 16°. Light + 45° — 45°. E is poarlised 71° to right, and 51° to left.

AZIMUTH 45°. Light + 45° — 45°. E′ is polarised 90° out of the plane of reflexion, and O′ a few degrees to the left of O and E.

AZIMUTH about 60°. E′ is polarised 76° to left. O′ vanishing with O and E.

AZIMUTH 90°. Light + 45° — 45°. E′ is polarised 70° to left, and O′ 53°. O′ is very faint when the prism images vanish.

AZIMUTH 180°. Light + 45° — 45°. E′ is polarised 68° to the left, and O′ 63° to the right.

AZIMUTH 0°. Light polarised 0° and 90°. E′ is polarised 90° to the left. O′ which is reddish, vanishes with O.

AZIMUTH 180°. Light polarised 0° and 90°. E′ is polarised 85° to the right. O′ vanishes with O.

With Oil of Anise Seeds.

AZIMUTH 0° and 180°. There is no polarisation at great incidences. One-half the spar pencil seems polarised 90° to the left, red light being polarised in the plane of reflexion.

AZIMUTH 90°. Light is almost wholly polarised about 100° to the left at the greatest incidences. At less incidences it is half polarised, red light being left.

With Alcohol.

In AZIMUTH 0°, 90°, and 180°, there is no change of polarisation. The spar image is polarised at a less angle of incidence than the prism image.

In order to observe the changes of polarisation in passing from one plane to another, I had three artificial faces made, slightly inclined to the three principal planes C, B, and E.

E1. *Face inclined 5° ½ to* **C.**

This face was used a few minutes after it was polished.

Polarising angle in principal section, 59° 38′.

Polarising angle perpendicular to it 58° 25′, much unpolarised light being left.

With Oil of Cassia.

AZIMUTH 0°. Light + 45° — 45°. E′ is polarised 61° to right, and O′ 73° to left.

AZIMUTH 180°. Light + 45° — 45°. E′ is polarised 67° to right, and O′ 76° to left.

In both these azimuths E is $\frac{1}{2}°$ O with common light, and is yellowish red.

Azimuth 0°. Light polarised 0° and 90°. E′ is polarised 84° to the right. O′ vanishes with O′, and is fainter and redder than E′.

Azimuth 180°. Light polarised 0° and 90°. E′ is polarised 90° to right. O vanishes with O, and is fainter and redder than E′.

B 1. *Face inclined* 5° 28′ *to* **B.**

In Azimuth 0°. With bright sun-light the spar pencil E is distinctly polarised about 14° to the right.

Azimuth 0°. Light +45° — 45°. E′ and O′ polarised about 13° to left.

Azimuth 0°. Light polarised 0° and 90°. E is polarised about 50° to the right, and O′ vanishes with O.

B 2. *Face inclined* 12° 8′ *to* **B.**

With common light, a small quantity is polarised in the plane of reflexion.

As the azimuth approaches to 90° on either side of the principal section, the light is polarised about 90° out of the plane of reflexion, much *bright blue* light being left. At small incidences the *blue* becomes brighter and purer. The light is orange when the principal section of the analysing rhomb is in the plane of reflexion, as if red light was polarised 90° out of the plane of reflexion, and blue light in that plane.

The experiments described in the preceding pages form but a small portion of those which I have made, both with artificial and solar light on the action of the surfaces of calcareous spar on common and polarised light. In submitting them to the Society, it is proper that I should mention the great difficulty of obtaining precise results in such observations. The extreme faintness of the reflected light; its imperfect polarisation in many cases at the angle of maximum polarisation; and the loss of one-half of the light in the analysing prism, render it very difficult to determine the deviation of the reflected pencil, especially when it is partially polarised, or unequally double; and I have been surprised at the great difference in the results obtained at different times with the same surfaces, when the observations were in both cases recorded as satisfactory.

The following general results, however, are sufficient to show the importance of this class of researches, in reference to certain questions in the undulatory theory which have not yet been solved, and perhaps to guide the mathematician to their solution.

1. In the reflexion of light, the surfaces of calcareous spar in contact with fluids, act in some cases as ordinary uncrystallised surfaces in the polarisation of light.

2. In reflecting common light, they polarise it out of the plane of reflexion,

the deviation from that plane varying with light of different colours, and with the angle of incidence.

3. In reflecting polarised light, they change its plane of polarisation, sometimes as in refraction, and sometimes as in reflexion.

4. In certain azimuths, and at certain incidences when the pencil is not completely polarised, much light, apparently unpolarised light, is left; and in many cases, upon all the surface, A, B, C, D and E, the reflected pencil consists of two oppositely polarised pencils, as in the reflexion of common light from the surface of murexide, chrysammate of potash, and a few other bodies.

5. The changes in the planes of polarisation, both of common and polarised light, are related to the axis of double refraction, that is, to the short diagonal of the primitive rhomb of calcareous spar.

XXI.—*Additional Observations on the Polarisation of the Atmosphere, made at St Andrews in* 1841, 1842, 1843, 1844, and 1845. By Sir DAVID BREWSTER, K.H., D.C.L., F.R.S., &c.

(Read 2d January 1866.)

Since the publication of my "Observations on the Polarisation of the Atmosphere," a long and elaborate Memoir on the same subject, by Dr R. RUBENSON, has appeared in the Acts of the Royal Society of Sciences of Upsal.* The observations which it contains were made with the finest instruments, and with a degree of accuracy which had not been attempted by previous observers. They were begun at Upsal in 1859, and carried on at Rome between the 6th of June and the 5th of August 1861, at Segni in the Campagna, between the 6th and the 27th of August 1861, and at Rome from the 5th of October 1861 to the 27th of July 1862.

Although Dr RUBENSON has devoted a section of his work to ascertain the cause of atmospherical polarisation, another section to the determination of the place of maximum polarisation, and a third to the causes which disturb the polarisation of the atmosphere, yet the chief object of his labours was to study the daily variation of the polarisation of the maximum point; and so fully has he treated this important branch of his subject, that the description of his polarimeter, of his method of using it, and the discussion of his observations, with the observations themselves, occupy three-fourths of his Memoir.

In his section on the Cause of Atmospherical Polarisation, Dr RUBENSON is led to the same conclusion which I had deduced from my earliest observations, namely, that the light of the blue sky is polarised by reflexion from the molecules of air, and not from vesicles of water with parallel sides, as maintained by CLAUSIUS, nor, as conjectured by others, from extremely minute drops of water, nor from molecules of aqueous vapour in an intermediate state between that of gas and that of vesicles.

According to ARAGO, the distance of the place of maximum polarisation from the sun was 89° 6′, the mean of six observations. I found 89° to be the mean of a great number of observations, but, like ARAGO, I considered 90° to be the nearest approximation to the place of maximum polarisation. Dr RUBENSON found it to undergo, as I did, great variations, chiefly from 88° to 92°, the general mean of

* Series 3d. tom. v. This Memoir has been published as a separate work in 4to, pp. 238. Upsal, 1864.

which, from his observations, was 90° 2′, half of which is so near to the polarising angle of air, which is 45° 0′ 32″, as to place it beyond a doubt that the light of the blue sky is polarised by reflexion from its particles.

In his section on the Causes which Disturb the Polarisation of the Atmosphere, Dr RUBENSON found, as I did, that clouds and fogs and smoke were the cause of the greatest perturbations; and he also found, as I had done,* that the intensity of the polarisation was reduced by the crystals of ice floating in the atmosphere which form the halo of 23°.

Dr RUBENSON has not observed the secondary neutral point which I found sometimes accompanying the neutral point of ARAGO, when it rises above the horizon, or is setting beneath it, and he has never been able to see, even under the fine sky of Italy, the neutral point which I discovered under the sun, and which, I believe, has not been seen by any other observer than M. BABINET.

In 1854, M. FELIX BERNARD† made several observations at Bordeaux, in order to determine the intensity of the maximum polarisation at different hours of the day. Though made only on four days of the month of October (from the 16th to the 19th inclusive), he found "that in proportion as the sun approaches the meridian the value of the maximum polarisation diminishes; that this value increases, on the contrary, in a continuous manner as the sun recedes from the meridian, and that it reaches its maximum when the sun is very near the horizon, the amplitude of this variation being about 0·09."

On the 16th October 1854, the maximum polarisation increased gradually after mid-day from 25° to 0° of the sun's altitude, from 0·6236 to 0·7051; and on the 19th October, from 5° to 35° of the sun's altitude, it diminished from 0·7083 to 0·6106. On these two days the maximum polarisation, at an altitude of 20°, was 0·6582, and 0·6464 respectively, the mean of which is 0·6523, differing only 0·12 from 0·64, as computed from FRESNEL's formula by M. BERNARD, from my observation in 1842, that when the sun's altitude was 20°, the intensity of the maximum polarisation at 90° from the sun was equivalent to that which would be produced by reflexion from the surface of glass, whose index of refraction was 1·486, at an angle of 65° 30′‡.

Before he became acquainted with the Memoir of M. BERNARD, Dr RUBENSON had completed his observations on the same subject; and, though they lead to a similar result, yet they possess a peculiar value from their having been made with the finest instruments, in different localities,—in almost all the seasons of the year, and under various states of the atmosphere.

From a careful examination of his observations, Dr RUBENSON arrives at the

* Treatise on Optics, p. 394, and Edin. Trans., vol. xxiii. p. 226.

† *Comptes Rendus*, tom. xxxix. p. 775, October 1854.

‡ Johnston's Physical Atlas—*Meteorology*, p. 10; or Phil. Mag., series 3d, vol. xxiv. p. 453, December 1847.

general conclusion "that *the atmospheric polarisation is subject to a diminution during the morning, and to an increase during the evening*, without one's being able to assign with certainty the precise hour of the minimum polarisation." These changes Dr RUBENSON found to be often influenced by perturbations commonly of short duration, and taking place indifferently at all hours of the day. They frequently arise from clouds or smoke, and probably often from *cirrus* too faint to be seen. According to Dr RUBENSON, the blue colour of the sky, in a normal state of the atmosphere, and 90° from the sun, is feeble at sunrise, increases rapidly in intensity, and attains to its maximum some hours before noon, the number of hours being different at different seasons. The intensity of the colour diminishes towards noon. It then increases, reaches a second maximum after some hours, and then diminishes quickly towards sunset. The relation between the blue colour of the sky and the intensity of its polarisation, is a problem which remains to be solved.

In 1859, M. LIAIS made observations on the polarisation of the atmosphere during his voyage from France to Brazil, and at San Domingo in the bay of Rio Janeiro. His observations were made at the beginning of dawn and at the end of twilight, with the view of determining the height of the atmosphere. From the observations made at sea he obtained 320, and from the observations made on land 340 kilometers, or 212 miles, as the height of the atmosphere.*

The most recent observations on the polarisation of the atmosphere were made by M. ANDRÈS POEY, between 1862 and 1864, under the tropical sky of the Havannah. The observations themselves have not been published; but he states, as one of the most important of their results, that "at sunrise and sunset the system of atmospherical polarisation ought necessarily to present two planes of rectangular polarisation, one vertical, passing through the eye of the observer and the sun, and the other horizontal, with four inversions of the signs, and four neutral points 90° from each other."

M. POEY adopts my theory of atmospherical polarisation, and the analogy which I pointed out between the lines of equal polarisation and the isochromatic lines of biaxal crystals, and between the same lines and those of uniaxal crystals when the sun is in the zenith,—the neutral points now meeting in the sun.†

It will be seen, from the preceding details, that the subject of atmospherical polarisation has become one of the most important branches of optical meteorology. It has already thrown much light on the constitution of the atmosphere; and when it has been studied in different climates, and at different altitudes above the sea, by Alpine travellers and scientific aeronauts, it will doubtless have still more valuable applications.

* *Comptes Rendus*, &c. tom. xlviii. pp. 109–112

† See *Comptes Rendus*, &c. tom. lx. p. 781, Avril 17, 1865.

Under this impression I have been induced to submit to the Society the rest of four years' observations which I made at St Andrews, and which, along with those already published, will exhibit the optical condition of the atmosphere on many days during every month of the year.

1841, April 28.—Wind west; fine day.

Mean Time.
3^h P.M. Polarisation a maximum in the plane passing through the sun and the zenith, and at 88° 16′ from the sun.

When the sun, or the antisolar point, rose or set, the neutral line of the polariscope bands, held and moved vertically, was a hyperbola, as shown in fig. 1.

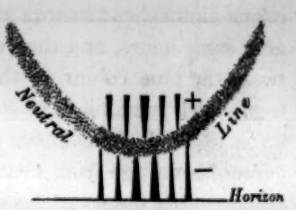


Fig. 1.

1841, April 30.

Mean Time.
2^h 5^m Polarisation a maximum in plane of zenith and sun, and at 78° 25′ from sun.

1841, May 6.

Mean Time.
3^h 30^m Polarisation, when a maximum, greater in plane of zenith and sun than in any other plane. At sunset the difference small. The polarisation was greater in the S. horizon than at the same point in the N. horizon, probably from the sky being there freer from haze.

1841, May 8.

Mean Time.
10^h 10^m Polarisation, or R, = 25½°, and a maximum in plane of zenith and sun. In the N.E., at an altitude of 40°, R = 14½°, and also much less in S.W. horizon.

1841, May 9.

Mean Time.
12^h NOON. Sky greenish blue. In plane of zenith and sun R = 13¾°. At 4^h R = 24½° and 22½° in different places, and *always greatest where the sky was bluest.*

1841, May 11.

Mean Time.
3^h 45^m P.M. R = 24½°, and a maximum in plane of zenith and sun. In other planes, R = 22½°.

1841, May 12.

Mean Time.
10^h 15^m A.M. The sky blue and unusually clear throughout the day. Barom. 30·1; Therm., 9^h P.M. 48°.
R = 26½° in plane of zenith and sun and a maximum. In other planes, 22½°.
11 40 R = 28½° in plane of zenith and sun.
21½° in lower planes.

White clouds; cumuli in motion.

Mean Time.	
12^h 0^m	R = 27½° in plane of zenith and sun.
	R = 20½ near horizon.
	R = 25½ at intermediate points.
1 20	R = 26½ in plane of zenith and sun.
	R = 21½ near E. horizon.

Near the large white cumuli R diminishes.

Mean Time.	
4^h 30^m	R = 30½° in plane of zenith and sun.
	R = 25½ in horizon.
6 0	R = 27½ in plane of zenith and sun.
	R = 24½ in horizon.
7 10	R = 30½ in plane of zenith and sun.
	R = 28½ in horizon.
7 35	R = 30½ in plane of zenith and sun.
	R = 29½ in horizon.
7 45	R = 28½ in plane of zenith and sun.
	R = 28½ in horizon.

See Edin. Trans. vol. xxiii. pp. 213–223, for the places of the neutral points on this day.

1841, May 14.—The sky in the forenoon has very little blue in it, being in its colour a French grey. R less than 14½°.

Mean Time.	
3^h 30^m	R = 14½°, and
	R = 18½ in a bluer part of the sky.

According as the thin white haze which masked the blue colour of the sky was removed or returned, the place of the neutral points constantly varied in their position.

In the evening the sky became clear, and R became 24½° and 26½°.

1841, May 16.—See "Edinburgh Transactions," vol. xxiii. p. 223.

1841, May 16.—Barom. 29·4. Windy. Considerably above the horizon R varied from 17½° to 14½°, as the blue sky was more or less distant from the white moving clouds.

At 7^h, when the blue was purer, R = 22½° at 45° of altitude in the S.

At 7^h 42^m R = 24½° at 20° altitude in the N.

1841, May 17.—Barom. 29·5.

Mean Time.	
1^h 20^m	R = 17½°, the maximum polarisation at 99° from sun in the plane of zenith and sun.
2 0	R = 17½° and 15½° at lower altitudes.

The following observations, from May 24 to June 3, were made in Edinburgh:—

1841, May 24.

Mean Time.	
11^h 10^m	R = 17½° maximum in plane of zenith and sun.
	R = 14½ in horizon.

After a cloud had passed the polarisation was diminished.

Mean Time.			
3^h	15^m	R=22½° maximum in plane of zenith and sun.	
		R=14½ elsewhere.	
5	0	R=26½ maximum in plane of zenith and sun.	
		R=24½ in horizon.	
		Babinet's neutral point near the sun.	
7	0	R=22½° in zenith and horizon.	
		Height.	
7	0	Arago's neutral point.*	22° 5′
8	0	Do. do.	17 48
9	0	Do. do.	15 50
		R=20½° in zenith.	
		R=22½ in horizon.	

1841, May 25.

Mean Time.		
6^h	0^m	Arago's neutral point in horizon, and the hyperbolic neutral line distinct.

1841, May 27.—Slightly hazy.

Mean Time.		
4^h	45^m	R=20½° in zenith.
		R=19½ in horizon.
		Babinet's neutral point not seen.

1841, May 28.

Mean Time.		
11^h	0^m	R=15½°. Hazy bands, ill-defined and *ragged*.

Observations resumed at St Andrews.

1841, June 3.—In the morning, R = 14½° and 18½°.

Mean Time.				
6^h	0^m P.M.	R=25½° in zenith and horizon.		
6	27	Arago's neutral point not above horizon.		
6	36	Do.	do.	very near the horizon.
6	43	Do.	do.	above and close to horizon.

See Edin. Trans. vol. xxiii. p. 214, for the height of Arago's neutral point.

1841, June 6.—Barom. 29·9.

Mean Time.			
4^h	45^m P.M.	R=14½° through zenith.	
		R=23½ 45′ above S. horizon.	
		R=22½ in S. horizon.	

In and near the horizon, the white bands of the polariscope are *bluish* on the side of the neutral line from the sun. Maximum polarisation more than 90° from sun, and diminished by clouds coming on.

Mean Time.			Arago.†
6^h	0^m	Sky very clear.	18° 36′
8	20		19 28
8	30		21 20

* The height of Arago's neutral point is to be understood as above the antisolar point, and that of Babinet as above the sun.

† The numbers under Arago and Babinet are the heights of their neutral points above the antisolar point and the sun.

Mean Time.			Arago.	
8h	36m	Sun set. Haze in S.E.		
8	45	R=28½° through zenith, and 26½° in horizon.		
9	10	R=28½ through zenith, and in S. and N. horizon.	17°	20′
9	17		21	39
9	30	Haze continued.	22	12

1841, June 8.—Barom. 30. Fine day.

Mean Time.		
11h	40m	R=21½° through zenith. R=19° in W. horizon.
1	5	R=29½ through zenith.
4	10	R=26½ through zenith. R=27° 30′ from N.E. horizon.
4	30	R=28½ 45° above N.E. horizon.
4	45	Babinet's neutral point and the neutral hyperbolic line clearly seen.
5	50*	R=20° to 24° as the sky was more or less clear.

At this hour the curious phenomenon shown in the annexed figure was seen, two hyperbolic neutral lines meeting in the sun.

Mean Time.		Babinet's N. Point above sun.	
6h	42m	13°	24′
7	50	26	37
8	28	15	16
9	10	20	24
9	30	15	0



Fig. 2.

Mean Time.			Arago.	
6h	45m			
7	30	R=27½° maximum polarisation.	19°	50′
7	35		20	25
8	20	R=24½° in S.W. horizon.		
8	23		21	10
9	10	Faint clouds near.	22	6
9	30		23	41

1841, June 9.—Barom. 20·9. Fine day; mackerel-sky occasionally.

Mean Time.			Babinet.	
3h	55m	Fine pure sky. R=25½° in N. horizon.	5°	0′
4	30		12	0
6	30	R=26½°+ in zenith and horizon.	17	15
7	7†		13	15
7	30	Fine cirri above the sun.	14	30
7	37	R=28½° in zenith and horizon.	16	7
8	0		17	20
8	40		18	5

Mean Time.			Arago.	
7h	45m	Antisolar point below horizon.	21°	0°
7	54		20	45
8	21		20	35
10	7		24	45

At 8h 40m clouds suddenly covered the whole horizon.

* See Edin. Trans. vol. xxiii. p. 221.

† During the preceding quarter of an hour a stratum of cirri surrounded the neutral point, and was just absorbed, when the observation was made.

1841, June 10.—See "Edinburgh Transactions," vol. xxiii. pp. 214 and 223.

1841, June 11.—Barom. 29·8. Wind north-east.

Mean Time.		Arago.
4^h 45^m	R=26½° in zenith, and 24½° in horizon.	
6 38	R=27° in zenith and horizon.	
7 34		19° 37′
7 42		19 3
8 5		19 0
8 18		18 52
8 36		18 50
8 52		18 32
9 3		19 12
9 15		19 17
9 25		19 20
9 33		21 37
9 45		23 39
9 55		25 22
10 0		25 18

Mean of observations within less than 4° of the horizon, 18° 40′. The evening was not so fine as yesterday.

1841, June 12.—Barom. 29·85. Wind north-east.

Mean Time.		
9^h 0^m A.M.	R=24½° in horizon, 26½° in zenith, and R=25½ about 20° alt. S.W. and S.E.	
11 22	R=24½ in zenith.	
1 0 P.M.	R=23½ in zenith. Sky fine.	

The day became cloudy, but suddenly cleared up at 8^h P.M., when R=28½° in zenith and horizon.

Mean Time.		Arago.
8^h 18^m		17° 22′
8 36		17 15
8 52	Therm. 50° R=28½° in horizon.	18 8
9 3		17 30
9 15		18 42
9 25		18 50
9 33		20 52
9 45		21 54
10 0		24 43

Mean of observations within less than 4° of the horizon, 17° 39′.

Mean Time.	Babinet.
8^h 25^m	17° 13′
8 54	17 12
9 8	17 20

1841, June 14.—Barom. 29·6.

Mean Time.		Arago.
7^h 45^m		18° 35′
7 51	R=26½° in N.E.	19 15
8 5		18 53
8 18		18 58
8 36		

1841, June 15.—Barom. 30·0 at 9h, and 29·8 at 10h A.M.

Mean Time.		Arago.	
8h	36m	18°	45′
8	52 R=25½° at 40° alt. N.E.	18	32
9	3	18	9
9	15	18	7
9	40	21	16
9	52 R=28½° at 40° alt. N.E.	21	52

1841, June 21.—Barom. 29·4.

Mean Time.			Babinet.	
7h	42m	R=24° at 40° alt., S. 21½° in zenith.	21°	30′
7	52	Clouds passing over the neutral point.	20	44
8	0		20	0
9	15		20	28

1841, June 2.—Barom. 29·68.

Mean Time			Arago.	
3h	0m P.M.	R=14½°. A faint whiteness over blue sky.		
8	31		17°	37′
8	47	R=14½° in horizon, and 25½° in zenith, and 24½° in alt. 40° S.W.	19	58
9	0		18	45
9	15	Sky not pure this evening.	18	5
9	30		18	0

1841, June 23.—Barom. 29·72. Sky impure.

Mean Time.			Arago.	
8h	5m	Clouds below the neutral point. Observations not satisfactory.	21°	30′
8	23		17	25
8	45		20	35
8	52		20	48

1841, June 27.—After three days of eastern haur and rain.

Mean Time.				
10h	0m A.M.	R=19½° in zenith plane, the sky being cloudy.		
1	0 P.M.	R=14½° at 20° alt. in E. Barom. 29·6 and rising.		
			Arago.	
7	30		21°	21′
7	45	R=22½° in zenith plane, and 21½° at 30 alt.	22	5
8	0		21	42
8	18		20	12

When light clouds covered the sky round and over the neutral point, the polarisation was + or vertical from the zenith to the horizon.

1841, June 28.—After a bad rainy day and the wind east, the sky cleared up in the evening and the wind became west.

Mean Time.		Arago.	
8h	50m P.M.	18°	26′
9	13	18	43

1841, July 17.—See "Edinburgh Transactions," vol. xxiii. p. 214.

1841, July 24.

Mean Time.		Arago.
6^h 40^m	R=14½°; cloudy sky.	25° 55′

1841, July 28.—Barom. 29·37. A clear blue sky; cloudy.

Mean Time.		Arago.
7^h 10^m	R=26½° to 28½°	18° 12′
7 40		18 43
7 57		17 53
8 10		18 5

1841, July 31.—Cloudy. Neutral point covered with minute cirri.

Mean Time.	Arago.
8^h 0^m	16° 45′
8 14	17 25

1841, August 6.—After two days of rain.

Mean Time.		Arago.
8^h 5^m P.M.	R=29½°. A cloud had passed.	16° 28′

1841, August 8.—Morning rainy; splendid evening.

Mean Time.		Arago.
6^h 50^m	R=29½°	16° 17′
7 5	R=28½	18 20
7 35	Clouds came on.	17 53

1841, August 10.—After rain.

Mean Time.	Arago.
7^h 45^m	18° 15′

1841, August 17.—Clear and windy.

Mean Time.	
9^h 0^m A.M.	R=21½° in zenith, and 15½° near horizon.

The blue of the sky, though very clear, was whitish, which always reduces the polarisation. Same day at Perth.

Mean Time.		Arago.
7^h 15^m	R=24½° in zenith, and 20½° in horizon.	20° 38′
7 30		19 24

During the whole day the blue sky became whiter and whiter, and the polarisation fell below 14½° out of the scale of the Polarimeter. Small black clouds appeared upon the white sky.

The observations, from the 6th to the 17th August, were made at the Bridge of Earn.

1841, August 31, September 6th and 12th. See "Edinburgh Transactions," vol. xxiii. p. 214.

1841, September 6.—See "Edinburgh Transactions," vol. xxiii. pp. 215, 223.

September 12. „ „ „ pp. 215, 223.

1841, September 13.

Mean Time.			Arago.
5h	55m A.M.	R=25½° zenith; 23½° horizon.	19° 10′
5	58		20 0
6	32 P.M.	R=25½° zenith.	18 16
6	38		18 0
6	42		17 27

1841, September 15.—Barom. 29·61. Splendid day.

Mean Time.			Arago.
10h	0m A.M.	R=27½° in zenith plane, and 25½° in horizon.	
10	18	R=28½°. Maximum 88° from horizon.	
6	0 P.M.		19° 54′
6	8		18 18
6	10	Sky not altogether pure.	18 47
6	28	R=27½° in zenith plane.	18 5

1841, September 21.—Barom. 29·95. Sky not pure; an eastern haur for three preceding days.

Mean Time.			Arago.
4h	50m	R=15½° in zenith, and 14° 30′ above S. horizon.	
4	55	Sky whiter in zenith than in horizon.	21° 59′

1841, September 23.—Barom. 29·47. Air damp, but no rain.

Mean Time.			Arago.
6h	0m P.M.	R=26½° in zenith, and 17½° 15° alt. S.	13° 30′

The sky impure. Neutral point covered with small black clouds; an eastern haur supervened.

1841, September 26.—Barom. 29·25. Day showery.

Mean Time.			Arago.
5h	49m P.M.	R=22½° zenith; 26½° in horizon.	22° 2′
6	10	Not free of clouds about neutral point.	20 2
6	15	The sky purer.	21 50

1841, September 29.—See "Edinburgh Transactions," vol. xxiii pp. 215, 223.

1841, September 30.—Barom. 29·03.

Mean Time.			Arago.
4h	27m	R=26° in zenith plane, and 25° 10° above S. horizon.	
4	37	Sky whitish.	20° 20′
4	43	Black cloud passed over neutral point.	19 49
4	49		22 29

1841, October 3.—Barom. 29.8. Wind north-east; cold.

Mean Time.			Arago.
4h	1m	R=27½° in zenith plane, and 26½° above horizon.	
4	44		21° 15′

A cloud passed, and the neutral point descended.

1841, October 12.—Barom. 29·1. Beautiful morning; the sun rose free of clouds.

Mean Time.			Arago.
6h 17m	A.M.	R=28½° in zenith, and 26½° in horizon.	21° 25′
6 24			18 20
4 54	P.M.	R=25° in zenith; 27½° near horizon.	18 1
5 10			19 57

1841, October 18.—Barom. 29·5. Wind west; a very fine day.

Mean Time.		Arago.
3h 0m	R=29½° in zenith, and 26½° near horizon.	
4 42		20° 5′

1841, October 23.—See "Edinburgh Transactions," vol. xxiii. pp. 215 and 224.

1841, October 25.—A cold day with a little rain. Wind north, and came round to the east at 4h.

Mean Time.		Arago.
3h 57m	R=29° in zenith plane.	19° 10′
4 13	R=29½° in zenith plane.	20 20
4 17	Slight clouds.	20 31
4 23	R=28¾° in zenith plane; 27½° 8° above S. horizon.	20 1

1841, October 26.—Barom. 29·6. Fine day and cold.

Mean Time.		Arago.
2h 0m	R=25½° in zenith, sun shining; 27½° sun not shining.	
2 29	Arago's neutral point rose in the N.E. above sea.	
2 29	R=25½° in zenith; 28½° in horizon.	14° 55′
4 22	R=29° in zenith; 29½° in horizon.	22 17
4 35		20 40
4 47	R=28° in zenith; 27½° in horizon.	20 35
4 53		22 39
		Babinet.
4 24		15° 5′
4 37		15 55
4 50		16 55
4 55		15 36

1841, October 28.—Barom. 29·9. Fine day.

Mean Time.		Arago.
3h 15m	A cloud had just left the neutral point.	16° 48′
8 39		19 40
4 23	A little cloud left about the neutral point.	20 2
4 39		21 50
4 50		21 28
		Babinet.
3 19	R=29½° in zenith; 28½° 10° altitude N. and S.	12° 15′
3 35		11 50
4 15	Maximum polarisation more than 90° from sun.	13 28
4 25		14 27
4 42	R=26½° in zenith, and at 10° above N. horizon.	14 5
4 47		15 4

1841, November 2.—See "Edinburgh Transactions," vol. xxiii. pp. 215 and 224.

November 4. " " "

November 15.—Barom. 29·5; therm. 35. Haze and clouds.

Apparent Time.		Arago.
2h 0m	R=27½° in zenith and horizon.	
2 15		13° 20′
3 56		18 10
4 1		17 40
4 5		19 50
		Babinet.
3 41		16° 31′
3 54		17 55
4 3		16 36
4 7		16 0

1841, November 16.—R=30° in zenith; 26½° near horizon.

Apparent Time.		Arago.
3h 45m	Sky whitish blue.	17° 58′
3 47		17 10

1841, November 17.—Barom. 29·43. Frost. See "Edinburgh Transactions," vol. xxiii. p. 228.

Apparent Time.		Arago.
11h 35m A.M.	R=26½° in zenith; 14½° near horizon.	14° 24′
12 0	Polarisation between the sun and horizon.	
		Babinet.
2 1		11° 30′
2 25		11 50
2 40		11 30
3 15		13 15
3 23		14 0
3 54		17 6
		Arago.
2 30	R=29½° in zenith; 26½° near horizon.	22° 31′
2 48	Fine day and fine sky.	23 34
3 19		21 30
3 51	R=29½° in zenith; 26½° near horizon.	19 0

1841, November 23.—Barom. 29·3. Cold, damp day; wind west.

Apparent Time.		Arago.
3h 57m		18° 51′
		Babinet.
4 0		15° 24′

1841, November 25.—See "Edinburgh Transactions," vol. xxiii. pp. 216, 224.

1841, Dec. 1.

Apparent Time.		Arago.
4h 3m		16° 41′
4 14	R=28½°; 30° above S. horizon.	17 51
		Babinet.
4 5		15° 34′
4 10		14 52

1841, December 5.

Apparent Time.		
11^h	0^m A.M.	R=25½° in zenith plane.

1841, December 7.—Neutral line convex towards the sun.

Apparent Time.	Babinet.
8^h 51^m A.M.	15° 4′

1841, December 11.—Barom. 29·4; therm. 41.

Apparent Time.		Arago.
3^h 46^m	R=28½ in zenith, and in 20° above horizon.	18° 27′
3 51		16 16

Although the sky appeared free of clouds, yet, upon close examination, extremely faint and transparent clouds reflecting no light, but rather darker than the sky, covered the whole heavens.

1841, December 17.—Beautiful morning.

Apparent Time.		Babinet.
9^h 7^m A.M.	R=27½° in S.W. horizon.	
9 13	Neutral line concave to sun.	13° 10′
10 30	R=27½° in zenith plane; 25½°, 30° above N.E. horizon.	

1841, December 18.—Splendid sky; without a cloud.

Apparent Time.	Babinet.
8^h 53^m A.M.	15° 55′
	Arago.
9 8	19° 52′

At 9^h the maximum polarisation R=28° in zenith plane, and far beyond 90° from the sun.

Apparent Time.		Arago.
3^h 17^m P.M.		19° 5′
3 32		17 25
		Babinet.
3 22	R=28° in zenith; 27½° in horizon.	17° 20′
3 36		18 25

1841, December 22.—Fine frosty day; clear sky.

Apparent Time.	Babinet.
9^h 23^m	14° 10′
	Arago.
9 33	20° 10′

R=27½° in zenith plane; 24½° in S.W. horizon, and 26½°, 10° above.

1842, January 6.—Fine day.

Apparent Time.	Arago.
2^h 34^m	19° 6′
	Babinet.
2 38	16° 18′

R=2½° in zenith plane; 28½°, 30° above E. horizon.

1842, January 7.—Very fine day, with haze.

Apparent Time.			Babinet.
9h	18m A.M.		15° 51′
12	0		13 53
			Arago.
11	52		20° 34′
12	4 P.M.		22 0
12	9	R=22½° in zenith.	22 37
3	25		20 40
4	17		19 49

At 9h 18m. R=24°, a maximum in horizon. The neutral line was *convex* to the sun. Sky clear, without clouds.

1842, January 16.—Ground everywhere covered with snow.

Apparent Time.	Babinet.
4h 12m	19° 25′

1842, January 17.—Fine clear day; therm. 36.

Apparent Time.			Babinet.
8h	37m A.M.	R=24½° at 35° alt. 20½° in horizon.	16° 55′
3	47 P.M.	R=25° in zenith; 24½° in horizon. Neutral line concave towards the sun.	

1842, January 21.—Barom. 29.77; dry, frosty day.

Apparent Time.		Arago.
3h	34m	R=27½° maximum polarisation in zenith plane, and 24½° near horizon. 19° 40′
		Babinet.
3	31	19° 3′

1842, January 25.—Snow covers the ground. Barom. 29·4.

Apparent Time.			Arago.
1h	12m P.M.	Arago's neutral point in horizon. R=17½° in zenith plane, and +15° in horizon.	
2	15		16° 45′
2	12	R=18½° in zenith, and 15° in horizon.	19 21
3	40	R=18½° in zenith, and at 50° altitude, 15°.	16 20
			Babinet.
2	15		17° 20′
3	36		18 30

1842, January 27.—Barom. 29·2; therm. 36° at 8h 30m.

Apparent Time.			Arago.
8h	34m A.M.	R=24½° near horizon; neutral line concave to sun.	
2	20 P.M.		11° 50′
4	37		20 40
2	32	R=25° in zenith plane and S. horizon.	
4	35	Thin clouds, almost invisible everywhere but above the sun	Babinet. 18° 40′

1842, January 28.—Barom. 29·6. Fine day; fresh.

Apparent Time.		Arago.
2h 7m P.M.	R=22½° in zenith; 25½° in E. horizon.	13° 5′
3 23	R=26½° in zenith; 27½° in S.E., and 26½° in S.W. horizon.	21 15
3 43		20 25
4 5		19 41
		Babinet.
3 21		18° 48′
3 47		18 10
4 2		16 52

1842, January 29.—See "Edinburgh Transactions," vol. xxiii. pp. 216, 224.

1842, February 2.—Very fine day, and clear sky till 2h.

Apparent Time.		
11h 30m A.M.	Arago's neutral point not risen. R=25° in zenith plane, 20½° in horizon.	
		Arago.
2 0 P.M.	A thick, impure sky.	16° 50′

1842, February 3.—Fine day.

Apparent Time.		
4h 43m		Arago. 20° 20′
		Babinet.
4 45		22° 1′

1842, February 4.—Barom. 30·15. Fine day; cloudy.

Apparent Time.		Arago.
3h 14m	R=20½° in zenith, 24½°, 50° alt. W. horizon.	18° 40′
4 0	R=25° in zenith, thin whitish clouds, 24½° in E. horizon, 10° alt., 22½° in alt., 20° W. horizon.	20 37
4 44		20 14

1842, February 5.—Barom. 30·05. Fine day; sky perfectly clear.

Apparent Time.		Arago.
1h 51m		17° 25′
1 44		23 10
3 48		22 15
4 9		20 50
4 31		20 30
3 51	R=28½° in zenith, 26½° to 18½° on E. horizon, neutral line convex to sun.	
		Babinet.
4 7		17° 20′
4 33	R=27½° in zenith.	19 42
9 5 A.M.	R=22½° 30° alt. S.W. horizon.	20 38
12 34 P.M.	R=27½° in zenith, 20½° in horizon. Dark haze in horizon from E. to W. by N.	
2 6	R=27½° in zenith to 14½° in horizon.	

1842, February 10.—Fine day, but cloudy.

Apparent Time.		Arago.
2h 57m	R=24½°, 25° above W. horizon.	16° 45′
3 58		19 20
4 45	R=26½° in north.	17 43
		Babinet.
3 59	R=29° in zenith, and at alt. 30° E. horizon.	18° 38′
4 5		19 4
4 41		21 50

Clouds came on, followed by great rain and wind, at 10h P.M.

1842, February 11.—Rain in the forenoon till $2^h\ 30^m$.

Apparent Time.		Arago.
$3^h\ 19^m$	R = 24½° 30° above S.E. horizon.	17° 33′
3 55	R = 29½ in zenith. Sky quite clear.	21 8
4 20	R = 29½ in zenith. Sky quite clear.	19 45
4 38		20 5
		Babinet.
3 22	R = 28½° in zenith, and in N. horizon.	
3 53		16° 19′
4 23		17 0
4 36		19 34
4 5	R = 29½° in zenith. Neutral line convex to sun. R = 28½° 15° alt.	18 36

1842, February 12.—Barom. 29·3. Rainy, with wind. Cleared up at 4^h.

Apparent Time.		Arago.
$4^h\ 18^m$	Clouds passed away.	17° 28′
		Babinet.
4 20		17° 12′
3 55	R = 24½°, but reduced to 20½° when watery clouds passed over the sky from W. to S.	

1842, February 15.—Rain in morning, then fine day. Wind west.*

Apparent Time.		Babinet.
$4^h\ 25^m$	R = 27½° in zenith to 22½° in S.E. horizon.	21° 58′
4 44		20 24
4 55	Barom. 30·05, therm. 43°; wind west.	20 30

Clouds came into S. horizon at $4^h\ 55^m$, and the whole of the N. and N.E. horizon, especially above the sea, was covered 6° or 8° high with a dark band of distant haze.

N.B.—At $3^h\ 48^m$, when the neutral point was 1° 57′ high, there was just above the sea horizon, H H, a portion *m n* of + bands, a continuation of those on the sea, so that there were two neutral points here. These were more fully developed at $3^h\ 58^m$, as shown in a former paper.†

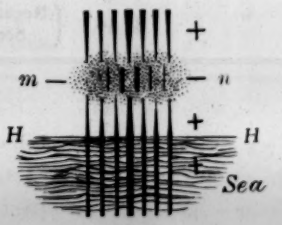


Fig. 3.

1842, February 16.—Barom. 30·16.‡

At noon, sun's alt. 21°, there is clearly a faint neutral point a little above the horizon, and 19° *below the sun.*

At $2^h\ 48^m$, though the bands at ARAGO's neutral point are all +, as in fig. 4, they are most weakened at *m n*, which is the effect of the secondary cause. R = 19½° in zenith, and in both horizons at 25° alt.

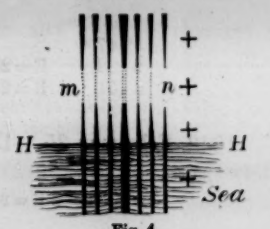


Fig. 4.

* See Edin. Trans., vol. xxiii. pp. 216, 224.
† *Ibid.*, vol. xxiii. p. 222. ‡ *Ibid.*, vol. xxiii. pp. 217, 228.

At $3^h\ 10^m$ the weak polarisation at $m\ n$ now extends down to H H. R=22½ in zenith, and in horizon at 25° alt.

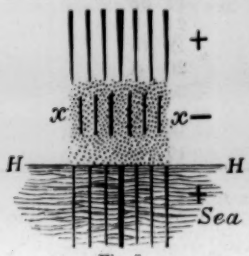


Fig. 5.

At $3^h\ 44^m$ the two neutral points are developed, as in the annexed figure, the — bands $x\ x$ being just distinctly visible.

1842, February 18.—See "Edinburgh Transactions," vol. xxiii. pp. 217, 229.

1842, February 19.—Fine day, with wind.

Apparent Time.		Arago.
$2^h\ 58^m$	R=26½° in S.E. horizon, alt. 20°.	
3 7	Neutral point 2° alt.	13° 38′
3 20	Secondary neutral point seen.	14 42
4 15	Fleecy clouds over neut. point. R=24½° S. hor.	20 0
4 40	R=24½° in zenith plane.	19 28

1842, February 21.—From $4^h\ 52^m$ to $4^h\ 57^m$, a secondary neutral point to that of Arago was gradually but imperfectly developed.*

1842, February 22.—Dull, cold morning, which cleared up about $1^h\ 25^m$, when R=21½° in clear sky, from which clouds had passed.

Apparent Time.		Arago.
$3^h\ 24^m$	R=25¾° in zenith, 22½° near W. and E. horizon.	15° 40′
3 38		17 29
3 44	Negative bands do not touch the sea horizon. Secondary neutral point in the horizon.	20 26
4 2		20 50
4 28		23 8
5 8		19 2
		Babinet.
4 6	Pol. of moon, R=3°; R=27½° in zenith.	17° 15′
4 24		16 19
5 6		19 5

1842, February 24.—Barom. 29·0.

Apparent Time.		Arago.
$3^h\ 47^m$		17° 20′
2 32	R=26½° in zenith, 27½° in S.E. horizon.	
3 51	R=23½ in zenith, and 25½° at 35° alt. N.W. horizon.	

1842, February 25.—Dull day; frost in morning; cleared up at $4^h\ 2^m$.

Apparent Time.		Babinet.
$5^h\ 9^m$	R=28° in zenith, 26½° in E. and W. horizon	17° 50′
		Arago.
5 12		18° 5′

* See Edin. Trans., vol. xxiii. pp. 217, 224, 228.

1842, March 2.—A wet day, the place of the sun being seen as a white spot.

Apparent Time.	
2^h	20^m The polarisation everywhere extremely feeble. BABINET's neutral point was nearly 75° above the horizon, or about 54° above the sea! See March 16.

1842, March 4.—Cloudy and sunshine.

Apparent Time.			
1^h	18^m	R=25½° in zenith, and 22½° at 30° alt. W. horizon.	
1	48	One plate of glass at 60° incidence compensates the polarisation on the sea horizon opposite the sun.	
3^h	53^m		Arago.
3	58		11° 13′
5	23		12 22
5	26		17 55
			Babinet.
5	38	R=27½° in zenith, and 22½° in horizon.	17° 22′

1842, March 7.—11^h 30^m R=28½° in zenith, to 18½° in horizon, but at 1^h 30^m, after showers of hail and rain, R=22½° in zenith.

1842. March 10.—Sky clear, and wind in west.

Apparent Time			
11^h	0^m	R=27½° in zenith.	
11	15	Neutral point seen below sun.	
3	14	R=28° in zenith, 24½° in horizon.	
4	0	ARAGO's neutral point not risen.	
4	10	The + bands scarcely seen in horizon.	
4	13	R=28° in zenith.	
			Arago.
4	15		12° 55′
4	20		13 56
4	27	The secondary neutral point just touching the sea horizon.	14 54

1842. March 13.—12^h 36^m R=26½° in zenith. Sky clear.

Apparent Time.			Arago.
4^h	27^m	The breach in the + bands not completed.	12° 15′
4	39	But at 4^h 39^m the neutral point is formed.	12 6

Both on the 10th and 13th ARAGO's neutral point is above the horizon, though masked by the cause which produces the secondary neutral point. Over a space of 3½° above the sea horizon, the + bands almost wholly disappear before the − ones are perceptible, and the neutral point is distinct on the sea horizon.

1842, March 16.—Barom. 29·96, the sun occasionally shining through a thickish haze in a sky without blue. Wind slight in south-west.

Apparent Time.	
10^h	45^m Polarisation the same as on March 2; BABINET's neutral point 30° above the sun, or more than 60° above the horizon!

1842, March 17.—Barom. 29·77. Much rain last night. Wind west; white clouds flying.

Apparent Time.		
10^h	20^m	R=26½° in zenith plane, and soon after 24½°.
10	50	R=20½ in zenith plane, and in a clear sky, over which clouds have passed.

1842, March 18.—Barom. 29·09. Wind and rain, day cold, and wind in west.

Apparent Time.		Arago.
3h 27m	R=25°, diminishing to 20°.	15° 48′
5 28		18 10
5 55		17 48
		Babinet.
5 30	R=30° in zenith plane.	19° 10′
5 57		17 40
6 10		20 12

1842, March 19.—Barom. 29·0.

Apparent Time.		Arago.
3h 54m	Polarisation of moon, 20½°; R=23° in zenith.	10° 37′
4 39	R=24° in zenith plane; sky very clear.	19 45
5 44		18 47
6 14	Polarisation of moon, 20½°; R=22½° in zenith.	18 45
6 19		Babinet.
5 48	R=26½° in zenith plane.	19° 30′
6 12		19 45
6 21		17 26

1842, March 24.—Cleared up at 1h. Fine day.

Apparent Time.	
2h 0m	R=22½° 50° above the horizon.
4 0	R=20½° in zenith plane.

1842, March 26.—Barom. 29·3. Cold wind from point north of west.

Apparent Time.		Arago.
5h 49m		18° 32′
6 16		19 25
6 31		18 4
		Babinet.
5 52	R=28½° in zenith plane.	19° 20′
6 34		19 40

1842, March 28.—Sky clear.

Apparent Time.	
4h 20m	R=26½° in zenith plane, and 18° and 20° in horizon.

1842, March 29h.

Apparent Time.		Arago.
6h 20m		17° 55′
6 36		17 50
		Babinet.
6 18		18° 40′

1842, March 30.—Wind; flying clouds.

Apparent Time.		Arago.
6h 27m	R=28½° in zenith, to 23½° in horizon.	18° 13′
6 45		17 55
6 52		19 37
6 24		
		Babinet.
6 48		20° 40′
3 10	R=21½° in zenith plane.	19 54

1842, April 2.

Apparent Time.		Arago.
6h	5m	19° 15′
7	4	19 42
		Babinet.
6	36	18° 5′
6	38	19 8
7	4	20 18

1842, April 3.—Fine clear sky; hail in the afternoon.

Apparent Time.			
11h	45m	Brewster's neutral point most distinctly seen. Distance from sun,	13° 0′

1842, April 5, 6, 8.—See "Edinburgh Transactions," vol. xxiii. pp. 217, 225, and 229.

1842, April 9.—Barom. 30·16. Wind east; bitterly cold.

Apparent Time.			Arago.
3h	25m	R=22½° in zenith plane. The sky clear.	
5	46		22° 7′
6	55	Effect of fog.	15 20
7	0		16 2
			Babinet.
5	49	R=15½° in horizon.	17° 10′
6	57		19 30

Between 5h 49m and 6h 57m a fog came on, and there were no neutral points.

1842, April 10.

Apparent Time.		
4h	5m	R=18½° in zenith, and 14½° in horizon.
4	22	R=27 in zenith, and 14½ in horizon.

Babinet's neutral point very near the sun, and no neutral point seen below the sun.

1842, April 13.—Barom. 30·12. Fine day.*

Apparent Time			Arago.
5h	48m		16° 20′
6	20		17 55
6	54		19 40
7	10		19 45
7	19	R=30½° in zenith.	19 4
7	29	R=32½° in zenith.	22 10

R increased from 25° at 4h to 32½° at 7h 29m.

1842, April 15.—See "Edinburgh Transactions," vol. xxiii. p. 230. Haze from west.

Apparent Time.			Arago.
5h	40		16° 25′
5	48		18 40
5	57	R=14½°, in zenith 18½°, 20° above N. horizon.	18 21
6	28	White nebulosity.	18 50
7	0		
			Babinet.
5	50		28° 20′

* See Edin. Trans., vol. xxiii. p. 225.

1842, April 16.

Apparent Time.			Arago.
5h	54m		17° 25′
6	31		22 22
6	59	R=27½° in zenith, 22½° in N. and 18½° in S. horizon.	19 50
7	21		18 55
7	35	R=18½° at moon.	0 45
7	46		23 50
			Babinet.
5	58	R=23½° in zenith, much less in horizon.	25° 40′
6	33	R=23° in zenith, 21° in W. and 18½° in E. horizon.	19 8
6	57		20 3
7	23	R=29½° in zenith, and 24½° in both horizons.	17 45
7	37	R=31° in zenith, and 29½° in horizon.	17 35

1842, April 17.—Slight haze.

Apparent Time.			
3h	30m	Brewster's neutral point distinctly seen, R=19½° in zenith, and 12° in S. horizon.	
			Arago.
5	34	R=17½° in zenith, 22½° in horizon; clear sky.	20° 10′
			Babinet.
6	3	Babinet's neutral point just risen.	19° 30′
7	35	R=28½ in zenith plane.	

1842, April 18.—Barom. 30·0.

Apparent Time.			Babinet.
7h	14m	Pol. moon=27½°, 29½° in zenith.	18° 45′
			Arago.
7	23	Pol. moon=28½°, 30½° in zenith.	17° 45′

1842, April 19.

Apparent Time.			Arago
7h	17m		16° 35′
			Babinet.
7	20	Pol. moon 14½° and a maximum.	18° 15′
7	37	22½°, and maximum 26½°.	19 10

1842, April 20.—See "Edinburgh Transactions," vol. xxiii. pp. 218, 230.

1842, April 21.— ,, ,, ,, p. 222.

Apparent Time.			
11h	30m	R=23½°, maximum at 90° from sun.	
1	10	R=25½°, maximum at 90° from sun.	
			Arago.
7	20		17° 55′
7	48	A fog came on.	14 24
			Babinet.
7	22		20 15

1842, April 22.—Fine day.

Apparent Time.			Brewster.
11h	10m A.M.	R=17½°; maximum polarisation in zenith 90° from sun.	
2	0	R=27° at 90° from sun in zenith plane.	12° 10′
3	0	R=29 at 88 from sun in zenith plane.	11 10
4	10	R=29½° at 90° from sun.	
			Arago.
6	55		20° 25′
			Babinet.
6	58	Thin clouds.	22° 15′

1842, April 24.—Barom. 29·84, rising.

Apparent Time.			
3h	0m	A haze. Babinet's neutral point 70° high; Brewster's not yet risen. After the haze had increased the sky cleared.	
6	21	Altitude of Arago's neutral point above horizon.	8° 40′
6	10	" " "	13 0
6	10	Secondary neutral point exactly in horizon.	

1842, April 25, 26, 27, 28, 29.—See "Edinburgh Transactions," vol. xxiii. pp. 218, 230.

1842, May 2.—Barom. 29·93; wind east.

Apparent Time.			Arago.
6h	18m		23° 45′
7	1	R=22½° zenith to 18½° in horizon.	24 45
7	45		20 15
			Babinet.
6	21	R=28½° maximum in zenith plane.	16° 30′

1842, May 3.*—China-ink sky; wind east.

Apparent Time.			
9h	0m A.M.	R=19½° maximum polarisation in zenith to 14½° in horizon.	
11	0	R=19½° maximum polarisation in zenith to 14½° in horizon; bands ragged.	
			Arago.
11	29	R=20°; maximum at 89° from sun.	10° 15′
12	15	R=20°.	9 25

1842, May 4.

Apparent Time.			Arago.
5h	56m		
6	2	The — bands of *secondary* neutral point distinct, and this point commenced.	17° 34′
6	13		20 46
6	16	The secondary neutral point distinctly formed.	21 1

* See Edin. Trans., vol. xxiii. p. 230.

1842, May 9.—Barom. 29·83.

Apparent Time.			Arago.	
5h	42m	R=22½° in zenith plane.		
6	7	Bands all positive.	19°	15′
6	18	Positive bands still in horizon.		
6	39		22	47′
7	28		23	21
			Babinet.	
6	45		15°	0′
7	30	R=19½° in zenith plane.	16	5

1842, May 15, 16, 17.—See "Edinburgh Transactions," vol. xxiii. pp. 218, 230, 231.

1842, July 16.—At Lacock Abbey, Wiltshire.

R=23° in a singularly fine day, this low polarisation indicating nebulosity, which collected and produced rain.

1842, August 2.—At St Andrews; Barom. 30·0.

Apparent Time.			Arago.	
5h	9m	R=20½° in zenith, and 14½° in horizon.		
5	27	The bands opposite the sun begin to weaken, and there is a second neutral point.		
6	15	Negative bands distinctly seen.		
6	0		20°	36′
6	26		25	1!
7	29		23	1
7	54		22	41
9	13		33	40!
			Babinet.	
6	32		13°	40′
6	39	Arago's secondary neutral point distinctly formed. A dark band along the horizon, below Arago's neutral point.		

1842, August 4.—Slight rain in morning; Barom. 29·5; wind west.

Apparent Time.				
5h	54m	R=25½° near horizon.		
6	41	Arago's secondary neutral point in horizon.		
7	6	R=29½° in clear blue sky.		
7	9	Altitude of Arago's neutral point above horizon,	15°	40′

1842, August 5.—Rain in forenoon. I observed a singular sky in the west, to the north of the sun and below him. The whole sky, from A A to the horizon H H, was clear, but the part A A was darker than B B, and of a deep China-ink blue, while B B was much paler. But, what was singular, these differently coloured spaces were separated by an irregular line *m m m*, showing that the whole space *m m m* H H was a thin sheet of cloud or vapour, terminating abruptly at *m m m*.

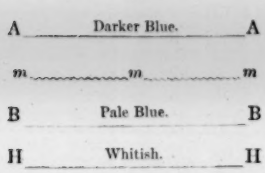


Fig. 6.

Apparent Time.			Arago.	
5h	40m	R=17½°, maximum polarisation at alt. 40°.		
7	21	R=27½° in zenith plane, and 26½° at alt. 40°.	17°	10′
7	25	A cloud approaching the neutral point.	16	35
7	40	R=28½°, maximum in zenith plane.	19	30

1842, August 6.—Barom. 29·6; rain at 5h P.M.

Apparent Time.		
7h 50m	R=28½° max. in zenith plane to 24½° in horizon.	
7 56	Altitude above horizon of Arago's neutral point.	19° 10′

Clouds around the blue space.

1842, August 11.—Barom. 29·62; rain in morning.

Apparent Time.		
5h 30m	R=23½° in zenith plane, and 20½° in S. horizon.	
5 51	+ Bands opposite sun almost gone at 1¾° above hor.	
		Arago.
6 14		6° 40′
6 46		14 35
7 40		20 35
8 4	Altitude of the two neutral points above the horizon.	22 20
		Babinet.
7 43		18° 25′
8 10	R=29° in zenith.	12 0

1842, August 17.—See "Edinburgh Transactions," vol. xxiii. p. 231.

1842, August 22.—Warm; fine day.

Apparent Time.		
2h 20m	R=24½° maximum polarisation in zenith plane to 19½° in horizon.	
		Arago.
5 52		18° 36
6 37	R=27½° in zenith plane.	21 16
7 26	R=28½ in zenith plane.	19 56
7 49		22 8
		Babinet.
7 52		13° 8′

1842, August 28.—See "Edinburgh Transactions," vol. xxiii. p. 231.

1842, September 9.—Barom. 29·1, after rain.

Apparent Time.		
5h 53m	R=26½° maximum polarisation in zenith, to 25½° in horizon.	
		Arago.
6 38		18° 57′

1842, September 13.—Barom. 29·93. Fine day.

Apparent Time.		
4h 39m	R=28° maximum polarisation in zenith plane.	
		Arago.
4 50	R=27½° maximum polarisation in 30° alt. N.W. horizon, to 24½° in horizon. In S. horizon, alt. 30° 26½° to 22½° in horizon.	15° 35′
5 29		18 35
5 58	R=29½° maximum polarisation. Pol. of moon 19½°.	20 17
6 36		20 0
7 2		16 24
		Babinet.
5 31	R=29° maximum polarisation in zenith.	14° 25′
5 56		15 40
6 38	R=29½° maximum polarisation in zenith.	16 6
7 6		19 8

1842, September 17.—Barom. 29·45, after a rainy day.

Apparent Time.		Arago.
6h 48m P.M.		17° 20′
		Babinet.
6 53	R=28½° maximum polarisation in zenith.	16° 25′

1842, September 18.—Fine blue sky. Barom. 29·57.

Apparent Time.		
3h 0m	R=21½° in zenith plane to 19½° in horizon.	
3 45	R=22½° in zenith plane to 20½° in horizon.	
4 20	R=25° in zenith plane to 23° in horizon.	
4 46	Fringes all + opposite sun and in horizon.	
4 47		Arago.
5 6		15° 28′
5 36		16 36
5 56		20 16
5 21	R=27½° max. polarisation in zenith to 24½° in hor.	19 40

1842, September 28.—Fine day.

Apparent Time.		Arago.
4h 32m	R=28° maximum polarisation in zenith plane.	
4 58		18° 36′

1842, September 29.—Fine day; cold; wind east.

Apparent Time.		Arago.
4h 37m	R=30½° maximum polarisation in zenith.	
5 11		17° 34′

1842, September 30.—Fine day.

Apparent Time.		
4h 18m	R=29½° max. polarisation in zenith to 26½° in hor.	
4 24	Neutral point not risen. Bands +.	
		Arago.
4 55		16° 11′
5 47		18 18
		Babinet.
4 58		15° 23′
5 44	R=29½° maximum polarisation in zenith plane.	17 28

1842, October 15.—Fine day. Barom. 30·0, rising.

Apparent Time.		Arago.
4h 32m	R=29½° maximum polarisation in zen. to 26½° in hor.	18° 0′
5 11		18 11
5 42		25 30!
		Babinet.
4 34		15° 23′
5 9		17 26
5 46		20 0

1842, October 19.—Barom. 29·3. Cold.

Apparent Time.		Arago.
4h 56m	R=27½° maximum polarisation in zenith plane.	19° 11′
5 5		20 9
		Babinet.
5 8		16° 39′

1842, October 20.—Barom. 29·62. Fine day; cold.

Apparent Time.		Arago.
4h 15m	R=26½° near S. horizon. Clouds in zenith.	14° 46′

1842, October 21.

Apparent Time.		Arago.
4h 49m	Neutral point above a cloud.	18° 13′

1842, October 24.—Barom. 29·33. Rain in the morning; cold.

Apparent Time.		Arago.
4h 28m		18° 46′
		Babinet.
4 32	R=27° maximum polarisation in zenith plane.	21° 59′

1842, November 9.—Barom. 29·06, after a storm of wind and rain.

Apparent Time.		Arago.
4h 41m	Polarisation of moon in S. horizon 25½°.	17° 20′

1842, November 14.—See "Edinburgh Transactions," vol. xxiii. pp. 218, 226.

1842, November 15.—Barom. 29·72. Hard frost in morning.

Apparent Time.		Arago.
2h 12m	Secondary neutral point in horizon.	17° 50′

1842, November 20, 21.—See "Edinburgh Transactions," vol. xxiii. pp. 219, 226.

1842, November 27.—Barom. 29·15, rising. A dark band along the horizon.

Apparent Time.	
3h 57m	R=27° in zenith, and 18½° in horizon. Arago's secondary neutral point in horizon, and primary one considerably up.

1842, December 3.—Barom. 29·95. Fine day.

Apparent Time.		
12h 46m	Arago's neutral point not risen.	
12 46	R=27½° maximum polarisation in zenith, 20½° in hor.	
		Arago.
2 16	R=28½° maximum polarisation in zenith, 18½° in hor.	19° 20′
4 23		24 22
		Babinet.
4 28		20° 15′

1842, December 17.—Barom. 29·58, rising after rain.

Apparent Time.		Arago.
3h 16m		18° 5′
		Babinet.
3 19	R=29° maximum polarisation in zenith.	17° 50′

1842, December 18.—Barom. 29·79. Raining occasionally.

Apparent Time.	Arago.
11h 13m	13° 45′
12 23	14 42

1842, December 22.—Barom. 29·38, falling. Rain.

Apparent Time.		Arago.
2h 43m		17° 50′
		Babinet.
2 46	R=29° maximum polarisation in zenith plane.	16° 10′

1842, December 23.—Barom. 29·01, after rain.

Apparent Time.		Arago.
3h 0m		18° 16′
		Babinet.
3 3	R=30° maximum polarisation in zenith plane.	19° 4′

1842, December 24.—Barom. 29·33.

Apparent Time.		Arago.
12h 3m	R=26½° maximum polarisation in zenith plane.	15° 28′
12 44	R=28° " "	15 5
1 32	R=27 " "	17 30
2 24	R=29 " "	18 40
3 8	R=27½° " "	17 52
3 37	R=29½ " "	19 14
		Babinet.
2 27	The point of maximum polarisation rising as the sun's altitude diminishes.	18° 28′
3 5		20 6
3 39		17 55!

1842, December 26.—Barom. 28·88.

Apparent Time.		Arago.
1h 3m	R=26½° maximum polarisation, alt. 30°.	16° 25′
3 27		17 15
		Babinet.
3 30	R=28° maximum polarisation in zenith plane.	17° 40′

1842, December 27.—Barom. 29·35. Sun shining through a dry haze, which continued all day. The lines in the sun's spectrum singularly sharp.

Apparent Time.		Arago.
11h 48m	R=26½° maximum polarisation in zenith plane.	15° 50′
12 4	R=23½ maximum polarisation in zenith plane, 14½° in horizon.	17 15
1 45	R=24° maximum polarisation in zenith plane.	20 25
2 35	R=27½° " "	21 30
3 15	R=29½ " "	19 0
		Babinet.
12 9		12° 25′
1 50		14 40
2 38		16 5

1842, December 28.—See "Edinburgh Transactions," vol. xxiii. pp. 219, 226.

1842, December 29.—Barom. 29·50. Clear in north.

Apparent Time.		Arago.
11h 40m		15° 25′
12 0		15 29
		Babinet.
11 44	R=26½° maximum polarisation in zenith plane. Slight clouds. R=28½° alt. 50°. Sky clearer.	17° 49′

1842, December 30.—Boisterous day; thin white clouds.

Apparent Time.		Arago.
2h 0m	R=22½° maximum polarisation in zenith plane.	
2 24		15° 5′

1842, December 31.—Windy, and sky cloudy.

Apparent Time.		Arago.
11h 53m	R=27½° maximum polarisation in zen. Sky impure.	16° 40′

1843, January 4.—Fine day.

Apparent Time.		Arago.
11h 32m	R=27½° maximum polarisation in zenith.	14° 41′
11 43		14 30
		Babinet.
11 35	R=23½° to 18°. Haze coming on.	15° 47′
1 51	Altitude of Arago's neutral point above hor. 4° 30′.	
	R=24½° to 18½°. Haze to east and south.	

1843, January 5.—At Rankeilour M'Gill; clear and cold.

Apparent Time.		Arago.
11h 27m	R=28½° maximum polarisation, 18½° in horizon. Neutral line convex to sun.	14° 44′

1843, January 10.—Barom. 28·5; very cold.

Apparent Time.		Arago.
2h 3m	R=29° maximum polarisation in zenith plane.	14° 25′
2 41	Polarisation of moon 21½°, 24½° in horizon.	

1843, January 11.—Barom. 28·72. Fine day.

Apparent Time.		Arago.
12h 35m	R=26½° maximum polarisation. Nebulosity in zenith.	15° 15′
1 47	R=29½° maximum polarisation in zenith. Clear sky.	
2 55	R=28° maximum polarisation. Slight nebulosity.	19 50
3 10	Polarisation of moon 15°.	

1843, January 21.—A misty day.

Apparent Time.		Arago.
2h 46m	R=19½° maximum polarisationin zenith 30° at 14° alt.	16° 40′
3 18	Misty.	10 6

The mist increased, and the maximum polarisation everywhere reduced to 14½°, and the two neutral points descended to the horizon several degrees.

1843, January 28.—Barom. 29·45. Very windy.

Apparent Time.		Arago.
12h 28m	Neutral point below horizon.	14° 10′
12 47	„ „	14 0
1 57	„ „	11 5
3 51	Misty.	22 41!
		Babinet.
3 54	R=28½° maximum polarisation to 20½° in horizon.	
12 28	R=26½ „ „ to 18½ „	14° 45′

1843, January 30.—Barom. 29·50. Windy.

Apparent Time.			Arago.
12h 18m		Neut. point below horizon, R=21°, maximum clear.	15° 40′
1 47	{	Neut. point below horizon, R=24½° in zenith to 14½° in horizon.	} 12 25
2 28			11 29
3 52	{	R=28½° maximum polarisation in zenith, to 21½° in horizon.	} 16 29
4 2			18 32
			Babinet.
3 55			19° 0′
3 10	{	R=27½° maximum polarisation in zenith, to 21½° in horizon.	} 18 25

1843, February 15.—Very cold day; clear only in north.

Apparent Time.	Arago.
2h 57m	16° 5′

1843, February 16.—Barom. 29·18, rising. Fine sky.

Apparent Time.			Babinet.
11h 56m		R=25° maximum polarisation, 20° in horizon.	
12 57			9° 40′
			Brewster.
12 57			11° 25′
			Arago.
3 28	{	R=29½° maximum polarisation in zenith, 24½° in horizon.	} 12° 52′
4 3	{	R=29½° maximum polarisation in zenith, 26½° in horizon.	} 18 40
5 0		R=30° " "	17 52
4 7			14 52
5 4			17 26

1843, February 17.—Barom. 29·6. Sky not clear in N. horizon.

Apparent Time.	Arago.
3h 6m	11° 28′
3 30	14 14

1843, March 4.—Barom. 30·08.

Apparent Time.		Arago.
3h 35m	R=14½° maximum polarisation in zenith plane.	16° 45′
3 46		17 30
3 54	Secondary neut. point 50′ high. Hazy in horizon.	17 57
4 6		20 30

1843, March 7.

Apparent Time.		Arago.
4h 40m	R=24½° maximum polarisation in zenith.	17° 0′

1843, March 8.—Barom. 30·13. Wind east; hazy.

Apparent Time.		Arago.
4h 14m	R=24½° maximum polarisation.	17° 47′

1843, March 12.—Barom. 29·34, after rain.

Apparent Time.		Arago.
4h 2m	R=25½° maximum polarisation. Polarisation of moon 7°.	13° 15′

1843, March 25.—See "Edinburgh Transactions," vol. xxiii pp. 220, 226.

1843, March 28.—Barom. 29·84. Wind east; dry.

Apparent Time.	Arago.
6h 2m	16° 45

1843, March 29.—Barom. 29·88. Fine day, cold; wind east; dry.

Apparent Time.		Arago.
3h 51m	R=28½°, 25½° in S. and 26½° in W. horizon.	
5 58		18° 35′
6 26		19 33
		Babinet.
6 1	R=29½° maximum polarisation in zenith, 28° in hor.	18° 22′
6 24	R=29½° „ „ „	18 27

1843, April 7.

Apparent Time.	Arago.
6h 54m	19° 0′
	Babinet.
6 48	16° 29′

1843, April 10.—Barom. 29·74. Very cold wind, north-west.

Apparent Time.	Arago.
6h 23m	20° 42′
	Babinet.
6 25	22° 23′

1843, April 11.—Barom. 29·80. Very cold.

Apparent Time.		Arago.
6h 43m	R=28½° maximum polarisation. Sky whitish blue.	17° 30′
6 48		17 45

1843, April 12.—Barom. 29·77.

Apparent Time.	Babinet.
4h 35m	41° 35′!

The sky was covered with a thick haze; the sun barely seen through it, and showers of hail falling occasionally. The bands a maximum above the sun, but disappeared 9° above horizon. A neutral point was seen at 25° alt. opposite the sun, but the bands below it seemed + ! though extremely faint.

1843, April 17.—See "Edinburgh Transactions," vol. xxiii. p. 226.

Apparent Time.		Arago.
6h 30m	R=25½° maximum polarisation in zenith, 20½° in hor.	22° 32′
7 4	R=29 „ „ „	20 44
7 30	R=29½ „ „ „	20 10

1843, April 19.—Nebulosity in zenith. Clouds round horizon.

Apparent Time.		Arago.
7^h 30	R = 25½° maximum polarisation in zenith plane.	18° 35′
		Babinet.
7 33		19° 0′

1843, April 28.—Barom. 29·44, after rain. Clear sky after clouds had cleared away.

Apparent Time.		Arago.
7^h 9^m		20° 23′
7 40		19 37
		Babinet.
7 3	R = 29° maximum polarisation in zenith plane.	16° 46′
7 44	R = 29 maximum polarisation in zenith, 20½° in hor.	18 0

1843, April 29.—See "Edinburgh Transactions," vol. xxiii. pp. 226–27.

1843, April 30.—Barom. 30·07. Morning, and rising. Not a cloud.

Apparent Time.		
1^h 0^m	R = 26½° maximum polarisation in zenith, 22½° in horizon.	
4 15	R = 26½ " " "	
5 43	Secondary neutral point forming.	
		Arago.
6 4		11° 20′
6 52	R = 29°. maximum polarisation in zenith, 22½° in hor.	19 20
7 33	R = 29½ maximum polarisation in zenith, 22½ in hor.	19 35
7 58		19 3

A brown haze rising up upon the blue sky. See "Edinburgh Transactions," vol. xxiii. p. 231.

1843, May 2.—Barom. 30·07. Wind east; no sun.

Babinet's neutral point near zenith, and polarised bands scarcely seen, excepting at 90° from sun.

1843, May 3.—See "Edinburgh Transactions," vol. xxiii. p. 227.

Apparent Time.		Arago.
6^h 49^m		18° 26′
		Babinet.
6 53	R = 30° maximum polarisation in zenith, 27° in hor.	14° 20′

Very clear in zenith, with a whitish sky.

1843, May 6.—Wind east; uniform China-ink clouds over the sky, through which the sun shone brightly, but ill-defined.

4^h 43^m.—Polarised bands distinct over the face of the sun and above him, but exceedingly feeble opposite the sun.

1843, May 11.—Barom. 30·0. Fine day.

Apparent Time.		Arago.
2^h 30^m	R = 20½° maximum polarisation in zenith plane.	
6 0	Neutral point not up.	14° 34′
6 12	R = 23½° maximum polarisation in zenith.	18 15

Whitish-blue sky. White clouds in horizon.

1843, June 13.—Barom. 30. Wind east.

Apparent Time.			Arago.
6h	56m		19° 15′
9	10		20 25
			Babinet.
7	0	R=27½° maximum polarisation in zenith plane.	25° 10′
9	13	R=29½ in zenith, horizon clear.	15 30

1843, June 14.—Barom. 30·07. Splendid day; wind east.

Apparent Time.			Babinet.
6h	12m	R=29½° maximum polarisation in zenith, 21½° in hor.	13° 30′
7	59	R=29½° „ „ 22½ in hor.	15 30
			Arago.
7	0	R=29½° maximum polarisation in zenith, 22½° in horizon. Neutral point in horizon.	11° 5′
7	56		18 20

1843, June 15.—See "Edinburgh Transactions," vol. xxiii. p. 231.

1843, June 16.—Barom. 30·0. Sky covered with white nebulosity.

Apparent Time.			
12h	20m	R=25½° maximum polarisation in zenith plane.	Arago.
7	0		10° 45′
7	38		17 50
			Babinet.
7	41	R=29½° maximum polarisation in zenith plane.	15° 55′

1843, June 21.—See "Edinburgh Transactions," vol. xxiii. pp. 220, 227,

1843, June 22.—Barom. 29·90. Wind east; fine day.

Apparent Time.			Arago.
8h	42m	Antisolar point in horizon. Clouds in zenith.	19° 15′

1843, June 23.—Barom. 29·92. Fine day.

Apparent Time.			Arago.
7h	17m	R=25° maximum polarisation in zenith, 18½° in hor.	15° 35
7	26		17 30
8	58		18 30
			Babinet.
7	30		15 10
9	0	R=27½° maximum polarisation in zenith, 22° in hor.	16° 50′

1843, June 24.—Barom. 29·92.

Apparent Time.			Arago.
7h	8m		17° 47

1843, June 26.

Apparent Time.			Arago.
7h	25m		21° 6′
8	52	Neutral point in the middle of a bright orange cloud.	17 33

1843, July 3.—Barom. 29·57, rising.

Apparent Time.		Arago.
7h 29m	R=26° maximum polarisation in zenith, 20½° in S. hor.	16° 28′

1843, July 6.

Apparent Time.		Arago.
6h 50m	R=28½° maximum polarisation in zenith, 22½° in hor.	11° 45′
7 1		14 15
7 21	R=18½° polarisation of moon.	17 32
8 13	R=29° maximum polarisation in zenith plane.	19 30
8 55		18 15
		Babinet.
7 25		13 40
8 15	R=28½° polarisation of moon.	16 3
8 52		17 11

1843, July 11.—Barom. 30·0, rising.

Apparent Time.		Arago.
6h 55m	R=29½° maximum polarisation in zenith; clear sky.	12° 28′
7 51	White clouds forming in many places.	21 11 !
		Babinet.
7 54		19° 10′

1843, July 21.—Barom. 29·5; no rain.

Apparent Time.		Arago.
7h 34m	Thin clouds in zenith and near sun.	20° 4′

1843, July 24.—Barom. 29·87, rising; no rain.

Apparent Time.	Arago.
6h 58m	17° 52′

1843, August 6.—Barom. 29·77, after a wet day.

Apparent Time.		Arago.
7h 27m	R=29½° maximum polarisation in zenith; sky clear.	18° 49′
		Babinet.
7 49		17° 39′

1843, August 9.—Fine day; rain yesterday.

Apparent Time.	Arago.
7h 37m	19° 34′
8 3	18 17

1843, August 10.—Splendid day; haze in zenith; slight white clouds. Barom. 29·97; hot.

Apparent Time.	
11h 38m	R=24° maximum polarisation in zenith plane.

1843, August 19.—Barom. 29·6, falling; haze all forenoon.

Apparent Time.		Arago.
$7^h\ 7^m$		18° 53′
7 51		18 30
		Babinet.
7 23	R=27½° maximum polarisation.	17° 50′

1843, September 6.—Barom. 30·05; splendid, hot day.

Apparent Time.		Arago.
$7^h\ 11^m$		23° 10′
		Babinet.
7 18		16° 32′

1843, September 9.—Barom. 30·05; fine day.

Apparent Time.		Arago.
$6^h\ 55^m$		19° 25′
		Babinet.
7 0		17° 23′

1843, September 13.—Barom. 29·98; fine day.

Apparent Time.		Arago.
$5^h\ 6^m$	Neutral point in horizon; R=25° maximum polarisation in S. horizon.	10° 55′
6 48		Babinet.
6 53	R=30° maximum polarisation in zenith, 23½° in S. hor.	16° 26′

1843, September 20.—Barom. 29·80; no rain.

Apparent Time.		Arago.
$6^h\ 14^m$	Clouds W., clear E; R=23½° zenith, 24½° horizon.	17° 42′

1843, September 21.—Barom. 30·0, rising.

Apparent Time.		Arago.
$5^h\ 46^m$	R=30° maximum polarisation in zenith, 25½° in horizon; not a cloud in the sky.	18° 59′
6 3		
6 28		17 55
		Babinet.
5 51		18 54
6 31		18 43

1843, September 22.—Barom. 30·28, rising; thick in horizon, with a brownish red light.

Apparent Time.		Arago.
$6^h\ 1^m$		18° 22′
6 7	R=29½° maximum polarisation in zenith, 22½° in hor.	19 58

1843, October 31.—Barom. 29·39; fine sunny day.

Apparent Time.		Arago.
$4^h\ 9^m$		15° 40′
4 22		17 56
4 59		20 49
		Babinet.
4 24	R=29½° maximum polarisation in zenith, 25½° in hor.	17° 8′
4 45	Polarisation of moon 24½°.	

1843, November 7.—Barom. 29·30, rising; fine day.

Apparent Time.		Arago.
$4^h\ 29^m$	R=29½° maximum polarisation in zenith, 26½° in S. hor.	18° 22′

1843, November 14.—Barom. 30·13, rising; fine day; wind north-west by west.

Apparent Time.		Arago.
$4^h\ 12^m$		18° 33′
		Babinet
4 17	R=28° maximum polarisation in zenith plane.	18° 45′

1843, November 20.—Barom. 29·27, rising; cold day.

Apparent Time.		Arago.
$4^h\ 36^m$		21° 32′
		Babinet.
4 37		18° 13′

1843, November 29.—Fine day.

Apparent Time.		Arago.
$3^h\ 31^m$		14° 14′

1843, December 1.—Barom. 29·94; fine day.

Apparent Time.		Arago.
$4^h\ 10^m$		18° 8′
		Babinet.
4 12		19° 26′

1843, December 6.—Fine day; wind west; clear sky everywhere.

Apparent Time.		Arago.
$3^h\ 3^m$		16° 58′
		Babinet.
3 7	R=28½°, 90° from sun.	18° 11′

1844, January 23.—Barom. 27·8, rising; fine day.

Apparent Time.		Arago.
$3^h\ 34^m$		18° 51′
		Babinet.
3 37	R=27° maximum polarisation in zenith plane.	17° 31′

1844, January 25.—Barom. 29·84; rain till 2^h P.M.

Apparent Time.		Arago.
$4^h\ 20^m$		18° 16′
4 26	R=28° maximum polarisation in zenith.	
		Babinet.
4 38	Polarisation of moon 17½°.	19° 0′

1844, February 3.—See "Edinburgh Transactions," vol. xxiii. pp. 220, 227.

1844, February 6.—Snow on ground.

Apparent Time.		Arago.
3h 13m		19° 1′
		Babinet.
3 19	R=25° maximum polarisation in zenith plane.	17° 58′
4 2	R=27 maximum polarisation in zenith, 19½° in hor.	

1844, February 7.—Clouds over zenith; snow.

Apparent Time.	Arago.
2h 18m	18° 13

1844, February 16.—Barom. 29·74; wind west; fine day.

Apparent Time.		
12h 14m	R=26½° maximum polarisation, to 19½° in horizon.	
1 58	R=26½ „ „ 20½ „	
3 1	R=23½ „ „ 18½ „	
		Arago.
3 14	Neutral point in horizon.	
3 20		10° 14′
3 24	Secondary neutral point in horizon.	14 33
3 33	Sky clouded.	15 31
4 6	Secondary neutral point disappears.	
		Babinet.
4 32		19° 49′

1844, February 21.—See "Edinburgh Transactions," vol. xxiii. p. 220.

1844, February 27.—Barom. 29·12., rising. Thaw.

Apparent Time.		Arago.
3h 16m	Polarisation of moon 17½°.	
3 44		14° 10′

1844, March 7.—Barom. 30·03, rising. Fine day.

Apparent Time.		Arago.
4h 48m	White nebulosity in zenith; R=13° maximum polarisation.	19° 20′

1844, March 27.—Barom. 29·70, rising.

Apparent Time.		Arago.
5h 40m	Polarisation of moon 22½°.	20 40′

1844, April 11.—Fine day and fine evening; wind west.

Apparent Time.		Arago.
6h 23m	R=27° maximum polarisation, 22½° in horizon.	18° 23′
7 1		18 37
		Babinet.
6 24		20° 50′
7 3		19 19

1844, April 22.—Fine day. Barom. 29·80.

Apparent Time.		Arago.
6h 29m	R=27½° maximum polarisation, 22½° in S. horizon.	19° 31′
7 15		20 34
		Babinet.
6 37		21° 32′
7 18	R=28½° maximum polarisation, 22½° in S. horizon.	17 28

1844, April 24.—Barom. 29·87. Fine day; windy.

Apparent Time.		Arago.
6h 1m		16° 55
6 38		20 30
		Babinet.
6 3		15° 58′

1844, April 26.—Barom. 29·84, rising.

Apparent Time.		Arago.
6h 24m		19° 20′

1844, April 27.—Barom. 30·07, rising.

Apparent Time.		Arago.
7h 1m	R=14°	20° 50′
		Babinet.
7 2	A great whiteness in the sky.	23° 22′

1844, May 2.—Barom. 30·25.

Apparent Time.		Arago.
5h 52m		21° 5′
6 0	R=15½° maximum polarisation in zenith, 14½° in hor.	22 25
6 33	R=17 " " 14 "	23 20
7 22	R=20 " " 14½ "	22 25
		Babinet.
6 5		13° 40′

1844, May 3.—See "Edinburgh Transactions," vol. xxiii p. 231.

1844, May 7.—Barom. 29·80. Whitish sky.

Apparent Time.		Arago.
7h 3m	R=26½° maximum polarisation, 20½° in horizon.	20° 2′
		Babinet.
7 5		16° 30′

1844, May 15.—Barom. 30·0, falling. Fine day.

Apparent Time.		Arago.
6h 36m		16° 50′
6 52		20 5
7 46		21 40
		Babinet.
6 50		16° 10′
7 51		21 15

1844, June 3.—Barom. 29·86. Wind west.

Apparent Time.		Arago.
8h 46m		20° 58′
		Babinet.
8 52		20° 35′

1844, June 10.—See "Edinburgh Transactions," vol. xxiii, pp. 220, 227.

1844, June 13.— ,, ,, ,, ,,

1844, August 20.—Barom. 29·77, rising. Fine day.

Apparent Time.		Arago.
6h 57m	R=23° maximum polarisation, 27° in horizon.	17° 1′
7 38	R=27½ ,, ,,	20 40
8 8		21 25
8 46		19 0
		Babinet.
8 50	R=29°	17° 15′

1844, August 26.—Barom. 29·77, rising. Fine day.

Apparent Time.		Arago.
6h 18m	Neutral point among small mottled clouds.	29° 0′ !

1844, August 29.—Barom. 29·92, falling. Fine day. A China-ink sky. Brewster's neutral point distinctly seen.

Apparent Time.	
2h 20m	R=19½° maximum polarisation in zenith plane.

1844, September 21.—Barom. 30·1; cold and clear sky.

Apparent Time.		Arago.
6h 16m	R=28½° maximum polarisation in zenith, 25½° in hor.	18° 55′
		Babinet.
6 18	Polarisation of moon 17½°.	17° 11′

1845, January 11.—Fine day, cold; wind west.

Apparent Time.		Arago.
2h 10m	R=28½° maximum polarisation in zenith.	8° 15′

1845, January 20.—Barom. 29·48. Fine day; frosty.

Mean Time.		
3h 10m	R=29° maximum polarisation in zenith.	Above Horizon.
3 15	Alt. of Arago's neutral point,	12° 56′
3 17	Alt. of Babinet's neutral point; clouds came on,	22 0

1845, January 24.—Barom. 29·55, rising.

Mean Time.		Above Horizon.
3h 37m	Alt. of Arago's neutral point,	11° 0′
3 59	Alt. of Arago's neutral point,	17 30
4 4	Alt. of Babinet's neutral point,	19 35
4 39	Alt. of Arago's neutral point,	13 35
4 41	Alt. of Babinet's neutral point,	24 0

1845, January 31.—Therm. 18° at 10^h P.M. of the 30th; 8^h A.M., therm. 12°. Barom. 29·54. rising. Fine frosty, clear day; ground covered with snow.

Mean Time.	
12^h	55^m R=26½° in zenith and in horizon.
12	55 Arago's neutral point in N, hor.; sun's alt. then 14° 45′.
1	40 Arago's neutral point still in horizon.
1	40 R=26½° in zenith.

1845, February 1.—Barom. 29·80. Frosty day; cloudy till 3^h.

Mean Time.			Above Horizon.
3^h	30^m	Alt. Arago's neutral point, R=20½° maximum polarisation in zenith to 14½° in hor.	8° 15′
3	45	Alt. Arago's neutral point, R=22½° maximum polarisation.	14 30

1845, April 8.—Barom. 29·06.

Mean Time.			Above Horizon.
5^h	35^m	Alt. Arago's neutral point,	9° 10′
6	1	„ „ „	20 20
5	39	Alt. Babinet's neutral point,	25 10
6	4	„ „ „	15 25

1845, April 15.—See "Edinburgh Transactions," vol. xxiii. p. 220.

1845, July 14.—On the top of Scuirmore, near Glenquoich.

Mean Time.			Above Horizon.
5^h	24^m	Altitude of Arago's neutral point, R=23½° maximum polarisation in zenith plane.	6° 40′

1845, September 6.—Barom. 30·10. Fine day; a milky sky.

Mean Time.			Above Horizon.
1^h	10^m	R=17° maximum polarisation in zenith plane.	
5	31	R=23° Arago's neutral point.	11° 0′
5	41	Arago's secondary neutral point seen in horizon.	13 24
6	36	Arago's neutral point,	19 10
5	43	Babinet's R=28½° maximum polarisation, 24° in horizon.	24 0
6	28		20 24

1850, July 1, 15, 29.—See "Edinburgh Transactions," vol. xxiii. p. 237.

1850, July 9.—Barom. 29·79, rising. Fine clear sky.

Mean Time.		
6^h	56^m	Bands just visible at the land horizon.
7	5	Bands invisible close to land horizon.
7	21	During the previous 21 minutes no trace of the + bands was seen. At 7^h 21^m they were seen, and became rapidly brighter.

The positive action which here produced the secondary neutral point was not strong enough to produce it by exhibiting the + bands counteracting the − ones, at some height above the horizon; but it was strong enough to neutralise them for 21 minutes, and to weaken them greatly when they did appear.

XXII.—*On the Laws of the Fertility of Women.* By J. Matthews Duncan, M.D.

(Read 5th February 1866.)

In a former paper* I described the variation of the fecundity of women according to age, and arrived at the conclusion that the climax of fecundity in women was at or near the age of 25 years. Researches, completed since that paper was read, regarding the variations of length and weight of children according to the mother's age, and regarding the mortality of childbed as influenced by the mother's age, have been published in the "Edinburgh Medical Journal." The results of these investigations seem to illustrate and confirm the statement made as to the age of the climax of fecundity, for I have found that, about that age, women produce the bulkiest children, as measured by length and weight; and about the same age of the mother there is the smallest mortality in childbed. As still further adorning the age of 25, I may add, that several sets of observations, including some made in St George's-in-the-East, London, and published in the eleventh volume of the "Journal of the Statistical Society," show a greater amount of survival and rearing among children born of women about that age than at any other; and recently Dr Arthur Mitchell has published a collection of cases of idiocy, with the respective ages of the mothers at the time of the idiots' births, and these also show a smaller proportion born of women about the age of 25 years than at greater and lesser ages.†

In the last portion of the paper first alluded to, having described initial fecundity, the age at which women are most likely to beget children soon after marriage, I said that I could not advance further without encroaching on another topic, viz., the fertility of marriage; or, as marriage is scarcely admissible as a term in physiology, the subject may be designated "sustained fecundity," or the laws of the fertility of women cohabiting with men during the child-bearing period of life. It is this subject which I propose here to enter upon. So far as I know, very little is ascertained or known in this department of physiology. The writings upon it are for the most part to be found in the works of political economists, and are chiefly confined to the single question of the rate of increase of a population under varying circumstances. To illustrate this topic, which is one of little interest to the physiologist, data are numerous and abundant. But when the writers referred to attempt to go deeper into the fundamental laws of the fertility of women, having very scanty materials and using them without care, they arrive at scanty results, which are either positively erroneous or of little value.

* Trans. Roy. Soc. of Edinburgh, vol. xxiii. p. 475, &c.
† Edinburgh Medical Journal, January 1866.

"The statistics," says Mr GRAHAM, registrar-general for England, "of a country in which the age of a mother at marriage, and at the birth of her children, is not recorded, must always remain imperfect, and leave us without the means of solving some of the most important social questions."* These data were secured for the first year of the registrations in Scotland. The results to be now described are derived from a study of a part of these registers, namely, those of Edinburgh and Glasgow for 1855, and are founded on an analysis of 16,301 families of wives.

CHAPTER I.—*The Fertility of the whole Marriages in a Population.*

On this subject much has been written, in latter times chiefly by Malthusians and anti-Malthusians, to whose works I refer generally. Elaborate comparisons are made between the fertilities of marriage in different countries; and there are exhibited variations to so great an extent, that they appear themselves to show the worthlessness of the data and of the comparisons instituted, at least in a physiological point of view. In illustration, I may refer to the variations described by M. BENOISTON DE CHATEAUNEUF,† in a paper on the intensity of fecundity in Europe at the commencement of the nineteenth century. The highest figure is derived from some villages in Scotland, where there are asserted to be six or seven children to a marriage, while his lowest figure is 2·44, the alleged productiveness of marriages in Paris.

We shall restrict our view to Great Britain, and we find the method generally followed of estimating the fertility of marriage to be the very old and simple one of dividing the number of legitimate births in any year by the number of marriages. "In 1861," says Dr STARK,‡ "for every marriage which occurred in Scotland there were born 4·64 legitimate children; that is to say, 464 legitimate children were born to every 100 marriages. During the same year, in England, only 3·89 legitimate children were born to every marriage, or 389 legitimate children to every 100 marriages." This is an exemplification of the ordinary method of calculating, and it is evident that the result derived is of not the slightest value as a contribution to the science of fertility. For, besides including marriages of all durations and at every fecund age, also second and third marriages, it includes many marriages at ages when fertility has entirely disappeared. It is impossible, indeed, to state what is the exact relation between the number of marriages in a population in any year and the number of legitimate children born in the same year, with a view to any physiological result. This aspect of the statement is, however, well worthy of being pointed out, because authors of respectability, whom it is needless to name, refer to and use these figures as exhibiting the fer-

* Registrar-General's Report for 1845, p. 14. (England).
† Annales des Sciences Naturelles, tome ix. 1826.
‡ Seventh Detailed Annual Report for 1861, published in 1865, p. xviii. (Scotland).

tility of continued married life in England and Scotland. MALTHUS was well aware of the real meaning of these figures,—of the fact that they merely show the relative frequency of marriage ceremonies and births in a population. "The rule," he says,* "which has been here laid down, attempts to estimate the prolificness of marriages, taken as they occur; but this prolificness should be carefully distinguished from the prolificness of first marriages andof married women, and still more from the natural prolificness of women in general, taken at the most favourable age. It is probable," he adds, "that the natural prolificness of women is nearly the same in most parts of the world; but the prolificness of marriages is liable to be affected by a variety of circumstances peculiar to each country, and particularly by the number of late marriages."

As a corollary from the preceding data, of value only in proportion to their value, it may be stated that the average duration of fertility in married women (including those who do not bear children) is about $7\frac{1}{2}$ years. For, as the intervals between marriage and the birth of a child, and between the births of successive children, is, on an average, 20 months, and as there are about $4\frac{1}{2}$ children to each marriage, we have about $7\frac{1}{2}$ years, counting from marriage, spent in producing that number.

British authors, as GRAUNT, SHORT, MALTHUS, SADLER, SENIOR, and those of later date, name 4, $4\frac{1}{2}$, or 5, as the fertility of marriage. MALTHUS, founding on such data, gives a wife eight years of fecundity to produce four children, a statement which cannot be passed over without the obvious remark that MALTHUS, so calculating, utterly neglects the force of the wise words which we have just quoted from his work.

I have nothing satisfactory to offer as to prolific marriages, to contrast with the statements given concerning all marriages. Dr LEVER† says, that "the average number of children consequent upon a prolific (not every) marriage is shown to be rather more than $5\frac{3}{4}$, but not amounting to 6." This is given without any authority stated or evidence detailed, and I know not what value to ascribe to it. In a physiological point of view, its value must be scarcely appreciable; for no allowance is made for the duration of the marriage, nor for the age of the woman at the time of the ceremony.

In St George's-in-the-East, London, the average number of children consequent on the prolific marriages was 5 to each marriage.‡ That is, 5 is the average number of children that has been born in all the families in a place at a given time. It tells nothing concerning the average number in completed families, or in still-growing families.§

* Essay on the Principle of Population, vol. ii. p. 6.
† On Organic Diseases of the Uterus, p. 5.
‡ Quarterly Journal of the Statistical Society of London, vol. xi., 1848.
§ Some interesting facts regarding the fertility of Esquimaux women are to be found in Roberton's "Essays and Notes on Physiology and Diseases of Women," p. 53.

Franklin says, that the females in America have, "one with another, eight children to a marriage;"* almost certainly a great exaggeration, especially as he does not even state, as a condition, that the marriages were prolific.

Chapter II.—*Annual Fertility of the Married Women of Child-bearing Age in a Population.*

Seeing the inexactness of the statements of which those just given are an example, Dr Stark has adopted another method of arriving at the comparative prolificness of marriages in England and Scotland. "In 1861," says he, "when the census was taken in England, the number of wives at the child-bearing ages, viz., 15 to 45, was 2,319,649; and as the number of legitimate children born during the year amounted to 652,249, this gives the proportion of one legitimate child for every 3·55 wives at the ages 15 to 45 in the population; or, in other words, every 355 wives in England, at these ages, gave birth to 100 children during the year. In Scotland, during the same year, there were 305,524 wives between the ages of 15 and 45 years; and as 97,080 legitimate children were born during the year, this gives the proportion of one legitimate child for every 3·14 wives at these ages in the population; or, in other words, every 314 wives in the population of Scotland, at these ages, gave birth to 100 legitimate children during the year."

While for every marriage in 1861 there were born in the same year in Scotland 4·64 legitimate children; every 3·15 wives between 15 and 45 in Scotland in the same year produced one legitimate child. Of 54,408 wives in Edinburgh and Glasgow in 1855 between 15 and 44 years of age, inclusive, 16,290 bore children fit for registering; or, 1 child was born to every 3·3 wives aged from 15 to 44.

If we adopt these latter statements, we must take care to note that they do not give the fertility of the whole marriages in a population, as the older and former statements in chapter first do. These latter give the annual productiveness of a mass of married women in our populations. The results of the two methods of computing the fertility of marriage cannot be contrasted, for each is concerned with an entirely different topic from the other.

Chapter III.—*The Fertility of the whole Marriages in a Population that are Fertile at a given time.*

In Edinburgh and Glasgow in 1855 there were 16,393 wives who bore first or subsequent children. Of these the necessary data are given in 16,301 cases These 16,301 mothers had produced 60,381 children; or 3·7 children constituted

* Sadler. Law of Population, vol. ii. p. 495.

the average production of each mother. In other words, excluding the large class of wives sterile in 1855, we have 3·7 as the average number of children (surviving or not surviving) in each family that increased in 1855.

To compare with the above result, we may observe 16,414 women delivered in the Dublin Lying-in Hospital during Dr COLLINS' mastership, who had borne 53,458 children, whose families, on an average, numbered 3·25; also 6634 women delivered in the same hospital during the period reported on by Drs M'CLINTOCK and HARDY, who had born 20,680 children; whose families, on an average, numbered 3·12.

As there can be no doubt that these 16,301 families are a fair sample of all the growing families in Edinburgh and Glasgow, it appears that the average size of growing families existing at a particular time in our population is between 3 and 4; and, if it be true that, on an average, children are born with an interval not exceeding twenty months, then all mothers child-bearing at any particular time have been on average less than seven years fertile. It is to be remarked, that this statement concerns only the families of wives mothers child-bearing at a particular time (*i.e.* in 1855), and is not to be compared with the corollary to Chapter I., which includes all families, and especially the mass of completed families.

The accompanying Table (I.) shows the data upon which these statements are founded. It, in addition, gives the percentage of children (surviving or not) in families of different numbers, that increased in 1855.

TABLE I.—SHOWING THE NUMBER AND PERCENTAGE OF MOTHERS BEARING RESPECTIVELY 1ST, 2D, AND 3D CHILDREN, AND SO ON; ALSO PERCENTAGE OF CHILDREN IN STILL-GROWING FAMILIES OF DIFFERENT NUMBERS.

Number of Child.	Number of Wives Mothers.	Percentage of Wives Mothers.	Percentage of Children.	Number of Child.	Number of Wives Mothers.	Percentage of Wives Mothers.	Percentage of Children.
1	3,722	22·83	6·16	11	152	·93	2·77
2	2,893	17·74	9·58	12	61	·37	1·21
3	2,534	15·54	12·59	13	34	·20	·732
4	1,982	12·16	13·13	14	11	·06	·255
5	1,543	9·46	12·77	15	6	·03	·149
6	1,221	7·49	12·13	16	2	·01	·053
7	848	5·20	9·83	17	2	·01	·056
8	641	3·93	8·49	18	1	·006	·029
9	425	2·60	6·33	19	1	·006	·031
10	222	1·36	3 67				

CHAPTER IV.—*The Fertility of Fertile Marriages lasting during the whole Child-bearing Period of Life.*

This subject may be stated in the form of a question. How many children does a fertile woman produce, living in wedlock from 15 to 45 years of age? The only collection of data known to me, which can throw light on this point, is that published in the "Report to the Council of the Statistical Society of London, from a Committee of its fellows, appointed to make an investigation into the state of the poorer classes in St George's-in-the-East."* In that district there were found 80 mothers married at ages varying from 15 to 19, and who had lived in wedlock at least 31 years. These fertile wives having lived nearly all the child-bearing period of life in wedlock, had borne on an average 9·12 children.

There are evident sources of inexactness in the above very limited data, which tend to diminish the average fertility; and it will be as near the truth to state 10 as the average fertility of fertile marriages lasting during the whole child-bearing period of life.

The conclusions given in further parts of this paper will show that the figure of 10 children, for 30 years of child-bearing life, is not indicative of each mother having borne a child every third year. The fertility, while it lasts, will be shown to be much intenser than this. The average interval between births of living children is hereafter shown to be 20 months, which gives about 17 years as the average duration of fecundity in a fertile woman living in the married state all the child-bearing period of life.

In his work on Abortion and Sterility, Dr WHITEHEAD gives no data which I can properly collate with those just given. After stating his belief that the actual duration of the child-bearing period in the female of this climate is about 20 years, he adds, that a woman, under favourable circumstances, has in that period 12 children. But as this includes abortions and premature deliveries, which he estimates at $1\frac{1}{2}$ for each individual, the figure 12 has to undergo that reduction for comparison with 10, and the approximation is very close.

SADLER states as a fact, "that marriages, on the average, are only fruitful for about a third part of the term of possible fecundity.†" But he nowhere, so far as I know, affords any evidence of this statement, and I therefore attach to it no importance.

* Quarterly Journal of the Statistical Society, August 1848, vol. xi.
† Law of Population, vol. ii. p. 276.

CHAPTER V.—*The Fertility of Persistently Fertile Marriages lasting during the whole Child-bearing Period of Life.*

This subject may also be conveniently stated in the form of a question. How many children does a fertile woman produce, living in wedlock from 15 to 45 years of age, and bearing children periodically up to the end of that time?

To this question I cannot give at once an answer founded on sufficient data; and I shall invert my usual mode of proceeding, stating the conclusion, namely, that 15 at least is the average number of children borne by a persistently fertile female in 30 years, before giving the reasons for it. These are as follows:—A persistently fertile woman, at all ages, is found to have borne one child about every 2 years; the average fertility of 15 mothers who have had each 26 years of persistently fertile life is 13. The fourth Table, to be hereafter given, showing an excess of fertility on the part of those long persistently fertile, or bearing children in the year of counting, would give 16 as the proportional fertility of 30 years of persistently fertile marriage, calculating from the actual values given for the other results in the Table. The deficiency of actual facts for settling this point is to be seen in the next Table (II.), where the number of women bearing children when above 26 years married, is only 7.

On this subject ALLEN THOMSON makes the following statement, which is remarkably accurate, seeing that it is apparently not founded on any analysis of documents. "A healthy woman," says he,* "bearing during the whole time, and with the common duration of interval, may have in all from 12 to 16 children, but some have as many as 18 or 20."

CHAPTER VI.—*Fertility of Persistently Fertile Wives at different Years of Married Life.*

The following Table (II.), from the 1855 Edinburgh and Glasgow data, gives at a glance the rate of yearly increasing production of wives mothers who are still fertile—that is, who produced a living child in the year of our census or counting. It is framed by adding together the whole children born of mothers having different durations of marriage, and dividing the sum by the number of mothers corresponding to each duration of marriage. The results will be found, on the whole, to tally pretty closely with those given in Table VI. It is easy to account for the differences between the two Tables. In the latter Table the wives arrived at different numbers of progeny are collated and compared, while in the former the wives arrived at different durations of marriage are collated and compared. The Table requires no further explanation; it is easily read.

* Todd's Cyclopædia of Anatomy and Physiology, vol. ii. p. 478.

TABLE II.—Showing the Average Number of Children that have been Born at the Completion of each Year of Persistently Fertile Marriage.

Duration of Marriage.	Number of Wives Mothers.	Number of Children.	Average to each Mother.
	16,301	60,381	3·70
1 year married and under,	3,172	3,336	1·06
2 years "	1,223	2,090	1·70
3 " "	1,540	3,195	2·07
4 " "	1,248	3,229	2·58
5 " "	1,193	3,645	3·05
6 " "	1,122	3,959	3·53
7 " "	870	3,414	3·92
8 " "	733	3,225	4·40
9 " "	719	3,447	4·79
10 " "	761	4,021	5·28
11 " "	624	3,502	5·61
12 " "	520	3,134	6·03
13 " "	441	2,878	6·53
14 " "	393	2,698	6·86
15 " "	372	2,659	7·15
16 " "	293	2,248	7·67
17 " "	240	1,918	7·99
18 " "	198	1,647	8·32
19 " "	177	1,541	8·71
20 " "	142	1,303	9·17
21 " "	115	1,116	9·70
22 " "	80	790	9·87
23 " "	56	557	9·95
24 " "	39	415	10 64
25 " "	8	95	11·87
26 " "	15	195	13·00
27 " "	2	25	12·50
28 " "	3	42	14·00
29 " "	1	14	14·00
30 " "	1	13	13·00

Chapter VII.—*Fertility of Fertile Wives at Different Periods of Married Life.*

With a view to comparison with the results given in Table II., I have prepared the following Table (III.), from the data of St George's-in-the-East, already referred to. The circumstances in which these data were collected, and their paucity, do not justify me in ascribing to them a value equal to those given in Table II., nor do I think they are well adapted for the purpose of the comparison for which they are adduced. But I know no other to refer to.

As in the Report of the Committee of the Statistical Society, the periods are counted from the birth of the first child, I have added to them 17 months ($1\frac{8}{12}$ths year), the average interval between marriage and birth of a first child, with a view to make the Table more easily contrasted with Table II.

TABLE III.—Showing, from the data of St George's-in-the-East, the Fertility of Fertile Wives Aged from 15 to 45 Years.

Years Married.	Mothers.	Children.	Average of each Mother.	Years Married.	Mothers.	Children.	Average of each Mother.
$2\frac{5}{15}$	56	59	1·05	$8\frac{5}{15}$	76	269	3·54
$3\frac{5}{15}$	60	88	1·46	$11\frac{5}{15}$	254	1,178	4·64
$4\frac{5}{15}$	54	99	1·83	$16\frac{5}{15}$	215	1,319	6·13
$5\frac{5}{15}$	66	184	2·79	$21\frac{5}{15}$	148	1,075	7·26
$6\frac{5}{15}$	57	163	2·86	$26\frac{5}{15}$	44	353	8·02
$7\frac{5}{15}$	60	196	3·26				

The direct results of this Table are given in the figures, and require no statement. But comparing it with the preceding Table, we observe that, as is easily understood, the differences between the fertile and the persistently fertile increase as the duration of marriage increases; and that, while the numbers of the children of fertile women is about a third of the years of duration of marriage, the numbers of the children of persistently fertile women is about a half of the years of duration of marriage. In other words, if these Tables are at all trustworthy, we may guess that the number (surviving or not) of a fertile married woman's family is about a third of the number of years since her marriage. But if, in addition to knowing that the married woman has a family, we know that she has just had an addition to her family, then we may guess that the number of her family is about a half of the number of years since her marriage.

From the same London data I have also framed the following Table, without doing any apparent violence to them, and with a result that is extremely interesting. The student will observe, that beside the data from St George's-in-the-East I have placed corresponding data extracted from the Edinburgh and Glasgow registers of 1855. The comparison of the fertility of a set of fertile wives—that is, all wives who have borne children some time during their still-continuing married lives—with that of a set of persistently fertile wives—that is, exclusively, of wives bearing at the ends of the periods under consideration (that is, in this Table, the end of their child-bearing lives)—is, as already said, marred, and loses value on account of the two sets being of very different numbers, different localities, and different populations. Taking it as it stands, we find that fertile women generally, living with husbands for 16 years before the conclusion of child-bearing life, have an average family of about $4\frac{1}{2}$; while persistently fertile wives—that is, wives bearing children at the end of their child-bearing lives—have an average family of $11\frac{1}{2}$. While fertile wives, married 21 years, before and up to the age of

45, have an average family of about 6; persistently fertile wives have an average family of 10½. While fertile wives married for 26 years, before and up to the age of 45, have an average family of 8; persistently fertile wives, in the same circumstances, have an average family of about 14. While fertile wives, married for 31 years, before and up to the age of 45 years, have an average family of 9; persistently fertile wives, in the same circumstances, have an average family which may be estimated at 16.

TABLE IV.—Showing a Comparison of the Fertility of Mothers and of Persistently Fertile Mothers.

		(St George's-in-the-East.) Wives Mothers.			(Edinburgh and Glasgow in 1855.) Wives Mothers bearing Children at the end of Child-bearing life.		
Age at Marriage.	Duration of Marriage.	Number of Mothers.	Number of Children.	Average fertility of each Mother.	Number of Mothers.	Number of Children.	Average fertility of each Mother.
15–19	At least 31 yrs.	80	730	9·12	...	...	16
20–24	At least 26 yrs.	179	1418	7·92	6	83	13·83
25–29	At least 21 yrs.	100	630	6·30	7	74	10·57
30–34	At least 16 yrs.	25	115	4·60	4	46	11·50

In this Table (IV.) it will be observed that the differences between the fertile and the persistently fertile are much greater than in the former (II. and III.), a circumstance which is easily explained. For, in the latter, all the women have been long married, and the persistently fertile have had time to far outrun the average fertility of all the fertile. It must also be noted, that all the women in the Table are fertile at or near the end of the child-bearing period, a time at which, it will be hereafter shown, the intensity of fertility is greater than at any other.

Chapter VIII.—*Degrees of Fertility of Wives Mothers of Families of different Numbers.*

Under this head, the first question that raises itself relates to the interval between marriage and the birth of the first child. In Table V. this question is found fully answered. In fertile marriages generally, there intervene about 17 months (1·38 year) between the ceremony and the birth of the first child. But in women of all ages this interval is far from being identical. As age increases above 25 years, the interval increases; the hope of the female is longer of being realised. The Table does not confirm this statement for wives married at 40 and upwards; but this is almost certainly a mere result of the paucity of the data at these ages. The whole tenor of the Table confirms the law of greatest fecundity according to age, meaning by fecundity, likelihood of having

children. For it is observed, that not only are wives most fecund from 20 to 24, but also that they begin the career of fertility sooner than their younger or elder sisters.

TABLE V.—Showing the Interval between Marriage and the Birth of a First Child in Wives Married at Different Ages.

		Mother's Age at Marriage.							Total.
		15–19.	20–24.	25–29.	30–34.	35–39.	40–44.	45–49.	
Years Married.	Less	94	325	126	44	15	4	...	608
	1	409	1,259	533	135	49	3	2	2,390
	2	83	202	88	45	17	2	...	437
	3	25	50	35	12	10	1	...	133
	4	8	31	13	8	1	...	...	61
	5	13	10	3	3	3	...	...	32
	6	5	14	6	1	1	...	...	27
	7	5	3	1	3	...	...	...	12
	8	1	3	1	...	...	...	...	5
	9	2	3	...	...	...	...	...	5
	10	...	1	...	...	...	...	...	1
	11	...	1	2	...	...	...	...	3
	12	2	1	1	...	...	...	...	4
	13	1	1	...	...	...	...	...	2
	14	...	...	...	...	...	...	...	...
	15	1	...	...	...	...	...	...	1
	16	...	...	...	...	...	...	...	...
	17	...	...	...	...	...	...	...	...
	18	...	1	...	...	...	...	...	1
	Total	649	1,905	809	251	96	10	2	3,722
Average interval between Marriage and Birth of first Child.	Year.	1·516	1·329	1·350	1·510	1·594	1·400	1·000	1·385
	Months.	or 18·2	or 15·9	or 16·2	or 18·1	or 19·1	or 16·8	or 12·0	or 16·6

It is noteworthy, that while the average interval between marriage and the birth of the first child is 17 months, the average interval between the births of successive children, however numerous, is a little under 20 months; the two intervals approximating one another so closely as to destroy all probability of the truth of the explanations usually offered for the delay of impregnation after a recent childbirth, and of the efficacy of continued lactation in retarding the occurrence of a new conception. And we shall soon see, in a quotation from Sadler, that he finds that women who do not suckle their offspring have as long an interval between conceptions as others. But, while Sadler by this demonstration destroys the only foundation for his invective against the rich who do not suckle, he nevertheless proceeds enthusiastically, as if the dictum of physiologists were valid, even after their argument was ruined.

Speaking of the interval between marriage and a first birth, SADLER* gives the following indefinite statement:—"Married females do not become fruitful, on the average, during the first year of their nuptials, but nearly so. A great number of cases which I have collected, with a view of determining this point, give three-fourths of them as producing their first child at the average of one year after marriage."

WHITEHEAD,† founding on the observation of 541 married women, of the average age of 22 years, makes out the average interval between marriage and the birth of a first child, to be 11½ months.

QUETELET‡ admits, with sufficient probability, as an average term, that the birth of the first-born takes place within the first year which follows marriage. His error, as those of the others, depends on the acknowledged want of documents.

It next comes to be inquired at what rate children succeed each other in families. This interesting topic is developed from the data given in Table VI. It is formed by dividing the whole years of duration of sets of marriages, of different durations, by the number of children born in the corresponding marriages; and it must be remembered, that as our data all spring from women who were fertile on the year of our census or counting, no women are included who, although fertile formerly, have now ceased to be so; and it is evident that, for the purposes of our argument, this is just.

TABLE VI.—SHOWING THE AVERAGE DURATION OF MARRIAGE AT BIRTH OF EACH SUCCESSIVE CHILD; AND THE AVERAGE INTERVAL BETWEEN THE BIRTHS OF THE SUCCESSIVE CHILDREN.§

Number of Child.	Number of Mothers.	Duration of Marriage in Months.	Average interval between successive Births.	Number of Child.	Number of Mothers.	Duration of Marriage in Months.	Average interval between successive Births.
1	3,722	17	17·0	11	152	235	21·4
2	2,893	38	19·0	12	61	246	20·5
3	2,534	64	21·3	13	34	263	20·2
4	1,982	90	22·5	14	11	281	20·1
5	1,543	115	23·0	15	6	280	18·7
6	1,221	137	22·8	16	2	336	21·0
7	848	162	23·1	17	2	252	14·8
8	641	181	22·6	18	1	252	14·0
9	425	203	22·5	19	1	204	10·7
10	222	225	22·5				
						Average	19·9

* The Law of Population, vol. ii. p. 30. † On Abortion and Sterility, p. 242.

‡ Treatise on Man, p. 15.

§ This is not a correct statement of the contents of this Table. The last column does not directly give the average interval between the births of successive children, but the average interval between marriage and the birth of the child, divided by the number of the children born. For brevity's sake, the title is left as it stands.

The first conclusions deducible from the data are:—

1. That the mass of early or first children, up to the third or fourth, come into the world in more quick succession than those that immediately follow.

2. That a mass of children, numbering from the fourth or fifth on to the tenth, succeed one another more slowly than those of the first category, and of the third.

3. That a mass of children, following the tenth, come into the world hurrying after one another with a gradually increasing rapidity, which excels that of all their predecessors (a circumstance which may, in part at least, account for the great mortality of women bearing children after the ninth.)*

While all these propositions are true of a large number of children, it must not be supposed that they directly indicate laws regulating the fertility of women. But the Table bears important information relative to this last topic. And it appears to me that the first of the three conclusions given above can be explained only by supposing what may therefore be held as equally well demonstrated:—

1. That wives bearing their early children up to the third or fourth, breed more rapidly than they subsequently do.

For the average fertility of all wives is at least 4 children; and the great mass of fertile wives is therefore included in the calculation. All the wives destined to bear large families, and furnish data for the second and third conclusions, are included in the data for first 4 children. The mass of children born in families numbering 10 and more, is not large enough to have great influence on the data, should it be the case that they are proportionately very quick breeders from the first.

If we now regard the mothers whose children have afforded the data for the second conclusion as to the rapidity of the succession of a mass of children, we shall have, I think, no difficulty in accepting the proposition,—

2. That wives produce their children, numbering from the third or fourth on to the tenth, at greater intervals than their earlier progeny.

For, in the calculations, the earlier and more rapidly succeeding progeny are included, and have their full influence, and diminish the periods given in the Table opposite children numbering from 4 to 10, reducing them below what they would be were pregnancies from 4 to 10 alone counted, exclusive of those from 1 to 4.

Regarding, now, the mothers of families numbering 11 or more, it is evident that their paucity, though not such as to destroy all their value, is such as to prevent their having a paramount influence upon the figures of the two preceding categories. It might therefore appear necessary to leave undecided whether their specially rapid bearing were a consequence of their great fertility, and therefore an acquired or secondary rapidity, or were an original condition true of even

* Edinburgh Medical Journal, September 1865, p. 209.

their earlier pregnancies. That the latter is to be accepted to the exclusion of the former supposition is evident, if we observe that the married life of the women with families above 10 is not long enough to admit of their having gone through the series of lengths of pregnancies given in the Table opposite each successive child. It is thus shown,—

3. That wives bearing more than 10 children, or wives bearing very large families, breed more rapidly than others during their whole child-bearing lives.

Wives, therefore, who bear numerous progeny, do so in virtue of two differences from other married women. They bear their children more rapidly, and they continue fertile longer than their neighbours.

Were the third conclusion just given not before us, it might be supposed that the rapid bearing of earlier children was a result of youth and vigour. This supposition is not only inconsistent with the third conclusion, but with the law to be hereafter demonstrated, that the oldest women, who are continuedly fertile, bear children more rapidly than any other.

The average length of interval between all successive children is (19·9), nearly 20 months.

I have frequently heard it said, that a fertile woman bears a child every 2 years. Some authors have made careful statements on this point. WHITEHEAD* says, that fertile women produce children every 20 months; but "this includes abortions, false conceptions, so-called premature deliveries, and all having an unsuccessful issue, the average amount of which will be rather more than one-and-a-half for each individual." Sir WILLIAM PETTY long ago laid it down, that "every teeming woman can bear a child once in 2 years." MALTHUS† adopts the same period, and refers to the Statistical Account of Scotland as confirming it. The number and exactness, however, of the data here adduced, and the circumstance that they include only children born alive (excluding still-born and abortions), leave no room for doubt that all the authors referred to under-estimate the rate at which married women bring children into the world.‡

On this point SADLER is so full and distinct that I quote his words. "The interval of time," says he, "at which the fruitful couples produce their children, calculated from the period of their marriage to the birth of their last child, including the greater prolificness of the first year, exceeds 2 years. It extends to between $2\frac{1}{4}$ and $2\frac{1}{2}$ years, if calculated from the first birth."§ In this calculation, as in that of the interval between marriage and the birth of a first child, SADLER evidently errs, making the former too long, and the latter too short. For both he gives no data; yet, in regard to the interval between the births of

* On Abortion and Sterility, p. 245.
† An Essay on the Principle of Population, vol. ii. p. 3.
‡ See also Roberton's Essays and Notes on the Physiology and Diseases of Women, p. 185.
§ Vol. ii. p. 30.

successive children he says:—"All the Tables are constructed upon the presumption of its certainty, and, happily, it is one which, on this very debatable question, has never been made the subject of controversy, and which does not admit of it. Nothing," he continues, "is more certain, or better ascertained, than the average period at which the human female, in a state of prolificness, reproduces. Were we, indeed, to form our general rules from particular exceptions, we should in this, as in all other cases, be grievously misled; we might conclude, for instance, that she would continue to multiply within the year; but general computations will rectify any such error, and conduct us to conclusions which are not only reconcilable with philosophy and truth, but resolvable into the ordinations of a merciful Providence. The human mother has to feed her infant for a period pretty nearly corresponding in length to that of gestation (I speak now as regards the necessity of the great mass of the community, with whom the question evidently rests); nature, therefore, has kindly ordained, as a general rule, that the period of impregnation shall be postponed till that essential duty is discharged, and for a period somewhat beyond it; and he must be ignorant indeed, who does not see most clearly that the health, and, indeed, frequently the existence, both of mother and offspring, are secured by this physical regulation of the common parent of mankind. The human being, in reference to the term of existence, multiplies later, and at longer intervals, and ceases to be prolific sooner, than any other animated being with whom we are acquainted; hence we find, on the average, that, in the maternal state, during its period of fruitfulness, the births are not so frequent as once in 2 years. Even in the rank of society which is absolved from the necessity (though not from the duty) of fulfilling one of the most important of the maternal offices, that of feeding, from their own bosoms, their infant offspring, and who too often avail themselves of that unnatural immunity, consequently removing what our physiologists regard as one of the physical impediments to an accelerated prolificness,*—even in this rank, I find the births are at intervals of about, but rather exceeding, 2 years; that period, therefore, as it respects the mass of the community, who are differently circumstanced in this respect, cannot be shorter. But arguments and proofs on this point are unnecessary, no writer having ever ventured upon supposing a shorter period than 2 years possible; and even Sir WILLIAM PETTY, when labouring to prove the possibility of a doubling every 10 years for a century after the flood, amongst his other suppositions, so extravagant if applied to the present era, only lays it down, that every teeming woman can bear a child 'once in two years.'"

* On this subject the work of Roberton already cited may be consulted; also a paper by Professor Laycock, quoted by Roberton.

Chapter IX.—*Fertility of Wives Mothers Married at Different Ages.*

Before discussing this and the next topics, it is necessary to remark that fertility may be maintained in degree in two ways—either by long-continuance or by intensity while it lasts. At present I omit entirely the consideration of intensity of fertility while it lasts, taking up this in the next part. But I shall show that, of a mass of fertile women, the younger are, on the whole, more fertile than the older. To demonstrate this I first adduce a Table (VII.) drawn from the data of St George's-in-the-East. It is evident here that the younger women 11 years married, and also those 21 years married, have, on an average, larger families than the elder, of whatever respective ages. It must be observed that the Table includes all wives, who, in a small selected population, have shown any fertility. And it must be added that the Committee of the Statistical Society have enunciated the same conclusion. I quote their own words :—"The following abstract will show the average number of children to each marriage, at the respective periods of 10, 20, 30, and 40 years after the birth of the first child, for each class of marriages formed at the four different quinquennial periods of life.

TABLE VII.—Showing the Fertility of Wives Mothers Married at Different Ages, from the data of St George's-in-the-East.

Mother's Age at Marriage.	$11\frac{1}{2}\frac{1}{2}$ Years Married. Average Number of Children.	$21\frac{1}{2}\frac{1}{2}$ Years Married. Average Number of Children.
15–19	5 0	7 7
20–24	4·5	7·0
25–29	4·4	6·4
30–34	3 4	3·0

"TABLE VIII.

Years elapsed since Birth of First Child.	Average number of Children to each Marriage formed at Ages			
	16–20.	21–25.	26–30.	31–35.
10	5·05	4·51	4·42	3·44
20	7·68	7·01	6·43	3·00
30	8·41	7·89	6·80	7·00
40	10·85	8·24	5·00	4·00

"It is thus obvious that marriages formed under the age of 25 are more prolific than those formed after that age, and that those formed between 16 and 20 years of age are still more so than those at any of the superior ages."*

As the doctrine generally taught, so far as I know, is exactly the opposite of that here sustained, it is important to establish the latter, if possible, by further proof. At another place I shall show the erroneous interpretation of the data which have been adduced in support of the opposite doctrine—namely, that marriages formed late in life are more prolific than those formed earlier.

The figures now to be adduced not only confirm the doctrine that early marriages are more fruitful than late marriages; they also explain it, showing that the younger married have a longer continuance of fertility than the older married, allowing to both the same duration of marriage, and all within the child-bearing period of life. So far as the demonstration has hitherto gone, we have shown that the younger are more fertile than the elder; that, excluding those who have no children, the younger will bear larger families than the older. We have not shown which bear their children most rapidly—that is, which have the greatest intensity of fertility while it lasts—leaving this topic for another chapter. We now proceed to show that, among the fertile, the younger have a longer continuance of fertility than the elder. It is this last circumstance which accounts for the greater fertility of the marriages of the younger. The following Table demonstrates this. It needs no explanation. The details are given in the footnote.†

TABLE IX.—Showing the Amount of Continuance in Fertility of Wives Married at Various Ages (as shown within Twelve Months).

Age of Mother at Marriage, ...	15–19	20–24	25–29	30–34	35–39	Total.
The number Child-bearing in the 5th year of Married Life is 1 in . . .	2·6	2·7	4·1	4·9	10·5	3 2
The number Child-bearing in the 10th year of Married Life is 1 in . . .	3 2	4·0	5·9	8·7	...	4 4
The number Child-bearing in the 15th year of Married Life is 1 in . . .	4·6	6·8	18·2	37·4	...	8·0
The number Child-bearing in the 20th year of Married Life is 1 in . . .	8·5	14·6	129·8	...	...	16·3
The number Child-bearing in the 25th year of Married Life is 1 in . . .	68·0	480 5	...	...	...	171·0

* Journal of the Statistical Society of London, vol. xi. p. 223.

† The Table IX. may be easily seen to be made up from the following five Tables, X., XI., XII., XIII., XIV. In these five Tables of the fertility of married life at different epochs, the number of

In order to derive from Table IX. more information as to the relative numerical value of the fertility of a mass of wives in the fifth, tenth, and fifteenth years of married life, and so on, I have framed the following Table (XV.) I have freely pointed out the sources of error in the fundamental figures of Table IX.; and after all I flatter myself that in these fundamental figures there is an approach to truth such as to justify the further deduction of Table XV.

wives mothers at the respective epochs is the actual registered number in Edinburgh and Glasgow in 1855. The number of wives of different ages is got by estimating, and the Carlisle Table of Mortality is used. The estimate is not made in the exactest way, but the errors will not injure the comparison of the figures with one another, as the same (perhaps unavoidable) error is introduced into all. The results probably give a near approach to the true degrees of fertility; for while among the child-bearing there are some omitted, there are probably fewer marriages omitted, and the numbers of wives as estimated would be too large were not a very high percentage taken off (1 in 100) for the special mortality of first confinements. (See Edinburgh Medical and Surgical Journal for October 1865, and Dr Stark's Report in the Seventh Annual Report of the Registrar-General for Scotland, p. xxxii.)

To find how many women, 5, 10, and 15 years married, are alive and not widowed in 1855, it would strictly be necessary to have the numbers married in 1850, 1845, and 1840, from which the estimates should be made. Instead of doing this, I have estimated from the number married in 1855. As the population is increasing not greatly, this error thus introduced will not be great.

It is partly with a view to correct this error that I have taken off an extravagantly high percentage for the mortality of first labours.

In making the estimate I have doubled the mortality, in order to exclude the widowed.

TABLE X.—Fertility of Wives in the Fifth Year of Married Life.

Ages at Child-bearing, ...	20–24	25–29	30–34	35–39	40–44	Total.
Number of Wives, ...	644	1686	1008	358	179	3875
Number of Wives Mothers, . . .	247	611	244	72	17	1191
Number Child-bearing, 1 in . .	2·6	2·7	4·1	4·9	10·5	3·2

TABLE XI.—Fertility of Wives in the Tenth Year of Married Life.

Ages at Child-bearing, ...	25–29	30–34	35–39	40–44	Total.
Number of Wives, ...	594	1528	902	313	3337
Number of Wives Mothers, . . .	186	381	153	36	756
Number Child-bearing, 1 in . .	3 2	4·0	5·9	8·7	4·4

TABLE XII.—Fertility of Wives in the Fifteenth Year of Married Life.

Ages at Child-bearing, ...	30–34	35–39	40–44	45–49	Total.
Number of Wives, ...	532	1360	782	262	2936
Number of Wives Mothers, . . .	116	200	43	7	366
Number Child-bearing, 1 in . .	4·6	6·8	18 2	37·4	8·0

only it is necessary to mention, that in this Table there are no actual values to keep it close to the truth. Taking, then, Table IX. as giving actual values, we have the fertilities for 1855; or for twelve months. But as 20 months has been shown to be the average time-unit of fertility, the fertilities of 1855 must be increased in like proportion; for as 12 is to 20, so are the fertilities given in Table IX. to the real fertilities. All the fertile women cannot be presumed to have shown that quality in 12 months, but all may be presumed to have shown it in 20 months. In this way, the following Table (XV.) may be held as an estimate of the comparative amount of fertility in living children, shown by wives at different epochs of married life.

The Table shows a gradually diminishing amount of perseverance in fertility as age advances. In illustration of the mode of reading it, I may state that about a half of all wives are fertile at the fifth year of married life; more than a third are fertile at the tenth year of married life; and only a fifth part of the whole wives arrived at the fifteenth year of married life are fertile, and so on.

Another interesting result is got from this Table (XV.), by comparing the different horizontal columns with one another. Reading the figures of adjacent columns obliquely from below upwards, we have a comparison of the fertility of a mass of wives of the same age, but of quinquennial differences of duration of marriage. And it is very interesting to observe that the younger married closely approach in fertility those married five years later in life, both being arrived at the same year of life at the time of the comparison.

Short and Sussmilch maintain that early marriages are not favourable to the population. But, so far as I know, they adduce no satisfactory evidence whatever for their belief. Yet they have considerable authority on their side, including the redoubtable Sadler, who arrays in his support the venerable names of Aristotle, of Plato, of Virgil, and of Plutarch.

TABLE XIII.—Fertility of Wives in the Twentieth Year of Married Life.

Ages at Child-bearing, ...	35–39	40–44	45–49	Total.
Number of Wives, ...	477	1171	649	2297
Number of Wives Mothers, . . .	56	80	5	141
Number Child-bearing, 1 in . .	8·5	14·6	129·8	16·3

TABLE XIV.—Fertility of Wives in the Twenty-Fifth Year of Married Life.

Ages at Child-bearing, ...	40–44	45–49	Total.
Number of Wives, ...	408	961	1396
Number of Wives Mothers, . . .	6	2	8
Number of Child-bearing, 1 in . .	68·0	480·5	171·0

TABLE XV.—Showing the Probable Amount of Continuance in Fertility, at Different Epochs, of Wives Married at Various Ages.

Age of Mother at Marriage, ...	15–19	20–24	25–29	30–34	35–39	Total.
The proportion Child-bearing about the 5th year of Married Life is 1 in . .	1·56	1·62	2·46	2·94	6·30	1·92
or a Percentage of	64·1	61·7	40·6	34·0	15·9	52·1
The proportion Child-bearing about the 10th year of Married Life is 1 in .	1·92	2·40	3·54	5·22	...	2 64
or a Percentage of	52·1	41·7	28·2	19·2	...	37·9
The proportion Child-bearing about the 15th year of Married Life is 1 in .	2·76	4·08	10·92	22·44	...	4·80
or a Percentage of	36·2	24·5	9·1	4·5	...	20 8
The proportion Child-bearing about the 20th year of Married Life is about 1 in	5·10	8·76	77·88	...	...	9·78
or a Percentage of	19·6	11·4	1·3	...	...	10·2
The proportion Child-bearing about the 25th year of Married Life is about 1 in	40·80	288·3	..	...	...	102·6
or a Percentage of	2·4	·35	...	...	...	·97

It is to be remarked that I only object to this statement of these authors so far as the increase of the population is concerned, and I do not consider the diminished chances of survival which children of very early marriages are believed to have. There can be, in my opinion, no doubt that early marriages are most favourable to the population; and, as I have already shown that wives under 20 are less fecund than those from 20 on to at least 24 years of age,* the fertility of the younger as a mass is the more striking. But although most highly fertile as a mass, the number of sterile among those married under 20 years of age is not inconsiderable, and it is probably this amount of sterility which, while satisfactory statistical evidence was deficient, has given rise to the error now commented upon. The authors referred to give no definition of what they mean by early marriage. Whatever they may mean, they have no good evidence for their doctrine.

Quetelet† enunciates on this topic the following doctrine, as a natural consequence from his data and reasonings. A marriage, says he, if it be not barren, produces the same number of births at whatever period it takes place, provided the age of the woman does not exceed 26 years. After this age the number of children, he adds, diminishes. Not only do I, of course, think Quetelet wrong in

* Trans. Royal Society, 1864.

† Treatise on Man, p. 15.

his conclusions, but I cannot in his work discover any satisfactory grounds for them.

Before passing from the perseverance in fertility of the early married, I will point out a difficulty of which it gives the solution. In my former paper, read to this Society, I showed that initial fecundity in wives from 15 to 19 years of age, is far less than at any age from 20 to 34; that is, of the young women very much fewer have children within two years; at the same time, I showed that the fecundity of the mass of wives in our population is greatest at the commencement of the child-bearing period of life, and after that epoch gradually diminishes; that is, those not the most fecund do, as a mass, produce most children. These two propositions are, at first sight, difficult to reconcile; and it is accordingly satisfactory to be able to show that the greater continuance in fertility of the mass of younger wives is the explanation of the apparent anomaly. To illustrate how the Tables read, in affording this explanation, I may state, that while I formerly showed that the wives from 15 to 19 years of age are not so fecund as those from 20 to 24 years of age, the Tables last adduced show that at the 5th year of marriage, the youngest married—that is, at ages from 15 to 19—already surpass all others in fertility, 1 in 2·6 bearing; that at the 10th year of marriage they still further surpass in fertility all others, 1 in 3·2 bearing; and that at the 15th year of marriage, they in a still higher degree surpass all others, 1 in every 4·6 bearing children, within a year.

Finally, under this head, I notice an important element of the inexactness that enters into the data here used, namely, the occurrence of second and third marriages. But the influence of this element is almost certainly inconsiderable for the following reasons:—In cases of second and subsequent marriages, the data used are exclusively those of the last marriage; as far as is known, a woman's previous marriage does not interfere with her subsequent fertility; it is shown in this paper, that a woman's previous fertility tends to ensure continuance in fertility; it will be shown that a woman's previous fertility tends to diminish the intensity of her subsequent fertility, when that is compared with the fertility of women late in being married and having family; and the admixture of second and subsequent marriages in the data which include only the last marriage, would tend to diminish the force of the results, as bearing out these conclusions. They are therefore all the more secure, from the fact of the intermingling of some data which would diminish their apparent influence.

Another inconsiderable element of inexactness I shall only mention, the occurrence of twins, and both being counted in the figures.

Chapter X.—*Fertility of Persistently Fertile Wives of different Ages.*

I may here repeat that, by persistently fertile, I mean fertile up till the time of the collection of the data. And I adduce a Table which clearly shows, so far

as the mass of figures can be relied on, that the fertility of the elder is greater than of the younger, while it lasts; or, in other words, the fertility of the elder is the more intense.

TABLE XVI.—Showing the Intensity of Fertility in Wives Mothers of Different Ages.*

Duration of Marriage.	Mother's Age.						
	15–19.	20–24.	25–29.	30–34.	35–39.	40–44.	45–49.
Under 5 years, . . .	1·128	1·519	1·825	1·844	1·827	1·698	1·200
5 years and under 10,	2·500	3·190	3·750	4·048	4·085	3·792	4·000
10 years and under 15,	...	5·333	5·453	5·903	6·197	5·964	6·500
15 years and under 20,	...	...	6·000	7·379	7·914	7·993	8·435
20 years and under 25,	...	...	...	7·000	9·396	9·718	10·528
25 years and under 30,	...	...	...	...	...	12·368	13·600
30 years, ...	...	...	...	...	...	...	13·000

The conclusion here arrived at is founded upon lengths of married life. Were the figures such as to give, instead of lengths of married life, lengths of intervals between the births of first and last children, the results would be still more striking; for I have already shown that in the case of the elder, fertility is later in beginning to show itself than in the younger.

If, as I have shown, the younger are more prolific than the elder, and if, as also I have shown, the elder are more intensely fertile, while their fertility lasts, than the younger in the same time; then, it necessarily follows, as a corollary, that the fertile women married younger have a longer continued fertility than the fertile women married older. In no other way can the younger surpass the

* The following Tables give all the details and calculations from which Table XVI. is constructed:—

TABLE XVII.—Of Women under 5 Years Married.

	No. of Mothers.	No. of Children.	Average to each Mother.
	7,183	11,880	1·654
Mother's age—16 to 19 years, . .	374	422	1·128
„ 20 to 24 „ . .	3,180	4,829	1·519
„ 25 to 29 „ . .	2,460	4,489	1·825
„ 30 to 34 „ . .	833	1,536	1·844
„ 35 to 39 „ . .	277	506	1·827
„ 40 to 44 „ . .	53	90	1·698
„ 45 to 49 „ . .	5	6	1·200

elder in their whole fertility; a conclusion which has already been otherwise demonstrated.

It may also be here pointed out, that the figures of Table VI. make it probable that elderly women when fertile, are more intensely so than younger, when their fertility has already resulted in a large family, for that Table shows that the children in large families are born very quickly one after another.

In his work on "the Law of Population," Mr SADLER enters upon this subject of the varying fertility of women according to age. Seeking arguments wherewith to overturn the teaching of MALTHUS, whose principles he hated as well as

TABLE XVIII.—OF WOMEN 5 YEARS MARRIED AND LESS THAN 10.

	No. of Mothers.	No. of Children.	Average to each Mother.
	4,637	17,690	3·815
Mother's age—16 to 19 years, . .	2	5	2·500
„ 20 to 24 „ . .	499	1,592	3·190
„ 25 to 29 „ . .	2,155	8,082	3·750
„ 30 to 34 „ . .	1,418	5,740	4·048
„ 35 to 39 „ . .	461	1,883	4·085
„ 40 to 44 „ . .	96	364	3·792
„ 45 to 49 „ . .	5	20	4 000

TABLE XIX.—OF WOMEN 10 YEARS MARRIED AND LESS THAN 15.

	No. of Mothers.	No. of Children.	Average to each Mother.
	2,739	16,233	5·930
Mother's age—20 to 24 years, . .	9	48	5·333
„ 25 to 29 „ . .	415	2,263	5·453
„ 30 to 34 „ . .	1,345	7,939	5·903
„ 35 to 39 „ . .	814	5,044	6·197
„ 40 to 44 „ . .	140	835	5·964
„ 45 to 49 „ . .	16	104	6·500

TABLE XX.—OF WOMEN 15 YEARS MARRIED AND LESS THAN 20.

	No. of Mothers.	No. of Children.	Average to each Mother.
	1,280	10,013	7·823
Mother's age—25 to 29 years, . .	7	42	6·000
„ 30 to 34 „ . .	253	1,867	7·379
„ 35 to 39 „ . .	721	5,706	7·914
„ 40 to 44 „ . .	273	2,182	7·993
„ 45 to 49 „ . .	23	194	8·435

opposed, he found data which at first sight appear to support his doctrine "that marriages are more prolific the longer they are deferred." Were this true doctrine, it would certainly go far to overturn the Malthusian system, and Mr SADLER might be justly proud of the demonstration. The facts which he adduces may, without cavil, be allowed to be, as he says, indisputable. It is his illogical use of the facts which has to be pointed out. Without pretending to enter on the defence of Malthusian notions, we accept Mr SADLER's challenge "to evade the demonstration," which the aforesaid facts afford. And it is of importance to do so, because, down to the latest authors, SADLER's facts and supposed demonstrations are generally quoted with unsuspicious approval.*

The first data afforded by SADLER are derived from the records of Dr GRANVILLE's experience as physician to the Benevolent Lying-in-Institution and the Westminster Dispensary, the calculations having been made by Mr FINLAYSON.

TABLE XXI.—OF WOMEN 20 YEARS MARRIED AND LESS THAN 25.

	No. of Mothers.	No. of Children.	Average to each Mother.
	432	4,181	9·678
Mother's age—30 to 34 years, . .	1	7	7·000
„ 35 to 39 „ . .	134	1,259	9·396
„ 40 to 44 „ . .	259	2,517	9·718
„ 45 to 49 „ . .	36	379	10·528

TABLE XXII.—OF WOMEN 25 YEARS MARRIED AND LESS THAN 30.

	No. of Mothers.	No. of Children.	Average to each Mother.
	29	371	12·793
Mother's age—40 to 44 years, . .	19	235	12·368
„ 45 to 49 „ . .	10	136	13·600

TABLE XXIII.—OF WOMEN 30 YEARS MARRIED.

	No. of Mothers.	No. of Children.	Average to each Mother.
	1	13	13·000
Mother's age—45 to 49 years, . .	1	13	13·000

See Boudin, Traité de Géographie et de Statistique Médicales, &c., tome ii. p. 59.

TABLE XXIV.—Showing the Effect the Postponement of the Marriages of Females has upon their Annual Prolificness. (Sadler.)

Ages when Married.	Average number of Births for each year of Marriage.	Ages when Married.	Average number of Births for each year of Marriage.
From 13 to 16, . .	·456706	From 29 to 32, . .	·589811
„ 16 to 20, . .	·503610	„ 33 to 36, . .	·776866
„ 21 to 24, . .	·520227	„ 37 to 39, . .	1·125000
„ 25 to 28, . .	·545163		

Now this Table is made from the data of lying-in charities. It is therefore not a Table of fertile women, but of persistently fertile women; for every woman was entered in the records only when she came to have attendance in her confinement. All that the Table offers is corroboration of the law enunciated in this chapter, that elderly women are more fertile than younger, so long as their fertility endures.

It is almost incredible that so acute a reasoner, as Mr Sadler is, could be so deceived by appearances, as to suppose his figures showed that marriages at 39 years of age are as fruitful as marriages of any inferior age, down to 13. Yet, for aught he says, he appears so to believe.

Sadler did, indeed, get the length of seeing that the Table just given was somewhat deficient. "It may," he says,* "perhaps be objected to the whole of the foregoing proofs, that they are derived from a register which cannot profess to give the whole number of children which the marriages it records shall produce, from their commencement to their termination, but only those which have been born to each up to a period within these limits, all the facts which it can record being necessarily retrospective ones. I shall, therefore," he continues, "proceed to another series of proofs of the same principle, which will at once silence every such exception, and afford a strong additional demonstration of its truth. These are derived from the registers of the peerage, which, as I have observed elsewhere, I have gone through in order to collect a body of authentic facts illustrative of many of the principles advanced in these volumes. As far as they relate to the subject before us, those facts are as follows:"—

* Law of Population, vol. ii p. 279.

TABLE XXV.—SHOWING THE EFFECT OF THE POSTPONEMENT OF THE MARRIAGES OF THE PEERESSES ON THEIR PROLIFICNESS. (SADLER.)

Period of Marriage.	Number of Marriages.	Number of Children.	Births to each Marriage.
From 12 to 15, . . .	32	141	4·40
„ 16 to 19, . . .	172	797	4·63
„ 20 to 23, . . .	198	1033	5·21
„ 24 to 27, . . .	86	467	5·43

To this Table of SADLER's many objections may be made, such as the paucity and insecurity of the data, as also their deficiency, the highest age of marriage included in them being only 27, and all notice of the important element of the duration of marriage being omitted.

SADLER not only erred in supposing he had demonstrated that late marriages are more prolific than early. He was ignorant also that a larger proportion of the elder than of the younger wives bears no children at all, and that an elderly woman continues fertile a shorter time than a younger, counting, in both cases, only up to periods within the child-bearing portion of life.

It is a natural, and I believe a true, notion, that twin-bearing should be a sign of intense fertility in woman, as the number of a litter certainly is in bitches, and other inferior animals. In confirmation of this notion, and of the law of intensity of fertility now demonstrated, we find that women are more likely to bear twins the older they are. This subject is capable of some interesting developments; but, as I have already elsewhere* entered upon them, I shall add no more in this place, merely remarking, that they were completed at a time when the law of intensity of fertility was only guessed at, and, therefore, when the explanation of the great twin-bearing of old women was not known to me.

In like manner, it is natural to suppose that the length and weight of children should go with intensity of fertility. But my researches† seem to show that this is not the case, but that length and weight of children go with the intensity of fecundity, or likelihood of bearing children, according to age. Professor HECKER, of Munich, has, however, elaborately shown that my conclusions on this head do not agree with those derived from his larger data.‡ Mine are based on 2087 observations only, and I am willing, in the meantime, to hold it as *sub judice*, whether his or my conclusions are to be received. His do appear to me the more

* Edinburgh Medical Journal for March and April 1865. † *Ibid.*, December 1864.
‡ Monatsschrift für Geburtskunde und Frauenkrankheiten, November 1865.

probable, because they bring the laws of length and weight of children, according to the mother's age, into agreement with the law of intensity of fertility here demonstrated.

CHAPTER XI.—*The Fertility of Elderly Women.*

So ardently did SADLER desire the triumph of his attack on MALTHUS, that he adopted the dream of MASON GOOD, who says, "that the usual term (of cessation of the menses) is between 40 and 50, except where women marry late in life, in which case, from the postponement of the generative orgasm, they will occasionally breed beyond their fiftieth year"!! * MASON GOOD refers to some extraordinary cases of pregnancy in old women, curiosities in physiology, but he adduces no good evidence in favour of the doctrine he here propounds. An opposite doctrine is taught by BURNS, an author equally celebrated, and much more worthy of confidence in a question of the kind now before us. "It is well known," says the Glasgow Professor,† "that women can only bear children until a certain age, after which the uterus is no longer capable of performing the action of gestation, or of performing it properly. Now it is observable, that this incapability or imperfection takes place sooner in those who are advanced in life before they marry, than in those who have married and begun to bear children earlier. Thus we find, that a woman who marries at forty shall be very apt to miscarry, whereas had she married at thirty, she might have born children when older than forty; from which it may be inferred, that the organs of generation lose their power of acting properly sooner, if not employed, than in the connubial state. The same cause which tends to induce abortion at a certain age, in those who have remained until that time single, will also, at a period somewhat later, induce it in those who have been younger married; for in them we find that, after bearing several children, it is not uncommon to conclude with an abortion; or sometimes after this incomplete action, the uterus, in a considerable time, recruits, as it were, and the woman carries a child to the full time, after which she ceases to conceive." My own opinion has always coincided with that so well expressed by BURNS; and I may add, that the curious observations regarding abortion at the close of the fertile period of life has its analogue in the lower animals. Several times I have been told by men of experience, that an old bitch often ends her career of breeding by a dead and premature pup. WHITEHEAD also‡ regards those pregnancies which occur near the termination of the fruitful period in women as being among the most commonly unsuccessful.

In Edinburgh and Glasgow in 1855, 53 women above the age of 45 bore living

* The Study of Medicine. 1822. Vol. iv. p. 63.
† Principles of Midwifery. Tenth Edition, p. 309.
‡ On Abortion and Sterility, p. 247.

children. Among these 53, only one was primiparous—her age was 49, and she had only been one year married; 2 bore second children,—1 was aged 46 years, and had been four years married—the other was aged 52 years, and had been three years married; 4 bore fourth children; 4 bore fifth children; 3 bore sixth children; 3 bore seventh children; 6 bore eighth children; 8 bore ninth children; 7 bore tenth children; 4 bore eleventh children; 1 bore a twelfth child; 4 bore thirteenth children; 2 bore fourteenth children; 1 bore a fifteenth child; 2 bore sixteenth children; 1 bore a nineteenth child. In short, the great majority of women child-bearing late in life are mothers of considerable families, not women for whom a postponement of the generative orgasm has to be imagined, a circumstance which destroys all shadow of ground for MASON GOOD'S supposition. *

This completes my remarks on the fertility of married women. But the subject is susceptible of further interesting developments, by an inverted method of proceeding, which I hope to carry out.

It is evident that the conclusions arrived at in this paper, or others still more definite, can alone form a sure basis for speculation in the great questions in political economy regarding population, and the various means of increasing it, or of retarding its excessive growth. And it is to be hoped that the promoters of that science will avail themselves of information which MALTHUS, SADLER, and their followers, evidently desired ardently to possess. In default of this information, they have fallen into many manifest errors in their groping after truth.

But it is not to the political economist alone that such information is valuable. It will form an element in the guidance of social life, and will certainly greatly contribute to the wisdom in council of the well-informed medical practitioner.

* For other corroborative evidence, see Roberton, Physiology and Diseases of Women, p. 184.

XXIII.—*On some Laws of the Sterility of Women.* By J. Matthews Duncan, M.D.

(Read 19th February 1866.)

Before commencing the discussion of the subject, it is necessary to make some definitions, with a view to avoiding the confusion which extensively prevails, from the neglect of the all-important definition of terms. I might be even more exact than I shall be, and excuse myself from adopting such a seeming improvement, on the ground that further refinement of definition would itself cause confusion in the present stage of advancement of our knowledge.

Absolute sterility, I shall hold to mean the condition of a woman who, under ordinary favourable cirumstances for breeding, produces no living or dead child, nor any kind of abortion.

Sterility, I shall hold to mean the condition of a woman who, under ordinary favourable circumstances for breeding, adds not even one to the population, or produces no living and viable child.

Relative sterility, I shall hold to mean the condition of a woman who, while she may or may not be absolutely sterile, while she may or may not be sterile, is, under ordinary favourable circumstances for breeding, sterile in relation to the circumstance of time; or, in other words, in relation to her age, and the duration of her married life.

Chapter I.—*Sterility of Marriages in our Population.*

Under this head, the age at marriage, and the duration of it, are not regarded. We simply compare the number of people living in the married state, without and with living children. The only information I have on this point is derived from the writings of Dr Stark.* "It is a pity," says he, "that when the census was taken up, a query had not been put to every married woman, whether she had borne children. We have at present no means of ascertaining what proportion of the marriages proves unfruitful; and it is no criterion to ascertain the number of married persons who had children living with them on the night of the census. Married persons who had a numerous family, may have none with them, because they are grown up, or are absent at schools or trades. We know, however, from other sources, that a considerable proportion of marriages proves unfruitful; and as it was shown that the married women of Scotland produce

* Census of Scotland, 1861. Population Tables and Report, vol. ii. p. xxxvi.

more children in proportion to their number, than the married women of England, it would have been extremely interesting to have ascertained whether that depended on more of the Scottish married women being fruitful."

On this point I may here interpolate the observation, that, in my opinion, it is highly improbable that there is any essential difference in the fecundity of women in England and in Scotland. The researches now published make it necessary, with a view to settling the question raised by Dr STARK, to look into the comparative ages at marriage of the women in England and Scotland; a difference in that respect alone may prove sufficient to afford the solution of the whole matter. And like remarks are applicable to the supposed great fertility of Irish women.

"As it may," continues Dr STARK, "however, give a distant approximation, it may be stated, that taking two of the largest registration districts of Glasgow, it was found, that of 14,523 married persons living together, 11,718 had children living with them; while 2805 had no children with them. This would yield the proportion of 80·686 per cent. with children, and 19·314 per cent. without children; or, without the decimals, that in every 100 married couples, 81 had children, while 19 had none. These numbers may be safely taken as the proportion in the town populations, seeing that for each district the proportions came out within a very small decimal fraction of one another; also from the circumstance, that in other tables which have been published in the Registrar-General's second detailed Annual Report, relative to the proportions of children born by mothers at different ages in Edinburgh and in Glasgow, the results of the one town almost exactly corresponded with those of the other."

CHAPTER II.—*Sterility of Wives.*

The wives who do not increase the population, may be called sterile. But a wife who has one or several abortions, or who bears one or several dead children, or to whom both of these events happen, adds not a unit to the population; yet such a wife cannot be said to be absolutely sterile. In order to discover the amount of sterility of married women, I proceed on the following plan. I take the registers of Edinburgh and Glasgow for 1855, and find what is the number of first children produced in that year. With this I compare the number of marriages in that year. It is evident that the first children only should be counted, for they indicate all the wives who are not sterile. If one living child is born to a marriage, that marriage is not sterile. Further, it is evident that, although the first births in 1855 will not all pertain to the women married in that year, it may be assumed that, if the marriages be nearly the same in number for a few contiguous years, the first births in one year will give the fertility very accurately

of any of the contiguous years. From this fertility, the sterility can be easily computed.

Now, in 1855, there were, in Edinburgh and Glasgow, 4447 marriages, and 3722 first deliveries of living children, leaving 725 marriges sterile, or 1 in 6·1. But in these figures are included 75 marriages which did not take place till after the women had passed 44 years of age, and these will damage the physiological value of the statement, as these 75 women could not be expected to be prolific.

Of women between the ages of 15 and 44 inclusive, there were married 4372; among wives of the same ages, 3710 had first children, leaving 654 marriages sterile, or 1 in 6·6. In other words, 15 per cent. of all the marriages between 15 and 44 years of age, as they occur in our population, are sterile.

The statement of the amount of sterility just given appears to me, from the largeness of the figures used, to be far more valuable than any other I know of. But on account of their great interest, I shall quote the statements of two authors.* "In the Dictionnaire des Sciences Médicales (vol. vi. p. 245; see also Neue Abhandlungen der Schwedischen Akademie der Wissenschaften, vol. xi. p. 70), it is stated," says Sir JAMES Y. SIMPSON,† "that HEDIN, a Swedish minister, had noticed that in his parish, composed of 800 souls, one barren woman is not met with for ten fertile. It is further stated, that FRANK asserted, but from what data is not mentioned, that it would be found on investigation, that in most communities containing 300 to 400 couples, at least 6 or 7 would be sterile, without anything in their physical condition to explain the fact. It seems to have been from this assertion of FRANK'S, that BURDACH, who is almost the only author who even alludes to the matter, has given the general statement, that one marriage only in 50 is unproductive (Dr ALLEN THOMSON'S excellent essay on Generation, in TODD'S Cyclopædia, vol ii. p. 478, foot note).

"For the purpose of ascertaining the point by numerical data, I had a census taken of two villages of considerable size, viz., Grangemouth in Stirlingshire, and Bathgate in West Lothian,—the one consisting principally of a seafaring population, and the other of persons engaged in agriculture and manufacture.

"The following form the results in these two places:—Of 210 marriages in Grangemouth, 182 had offspring; 27 had none; or about one marriage in 10 was without issue. Of the 27 unproductive marriages, all the subjects had lived in wedlock upwards of five years, and in all, the female had been married that period before she reached the age of 45. Again, of 402 marriages in Bathgate, 365 had offspring; 37 had none; or about one marriage in 11 was unproductive. There were at the same time living in the village 122 relicts of marriages, and of

* LEVER'S statement I here quote, but I cannot ascribe much value to it, because no evidence is adduced, and because there is an evident numerical error in some part of the passage. He says, "It is found that $\frac{1}{20}$th, or 5 per cent. of married women are wholly unprolific."—*Organic Diseases of Uterus*, p. 5.

† Obstetric Works, vol. i. p. 323.

these 102 were mothers; 20 were not mothers; or about 1 in 6 had no family. In all, of 467 wives and widows, 410 had offspring; 57 had none; or about one marriage in 8 was unproductive. Of these last 57, six had not been 5 years married, and there were other six above the age of 45 when married. If we subtract these 12, we have, of 455 marriages, 410 productive; 45 unproductive; or 1 in $10\frac{1}{2}$th without issue.

"Returns such as I have just now adduced are exceedingly difficult to obtain, in consequence of no registers being anywhere kept, so far as I know, that could be brought to bear upon the question. If it had been otherwise, I would here, if possible, have gladly appealed to a larger body of statistical facts, in order to arrive at a more certain and determinate average of the proportion of unproductive marriages in the general community. For the purpose, however, of extending this basis of data, I have analysed, with some care and trouble, the history of 503 marriages, detailed by SHARPE, in his work on the 'British Peerage,' for 1833. Among British peers, there were 401 marriages with issue; 102 without issue; or of 503 existing marriages among British peers in 1833, 74 were without issue, after a period of five years. Of those who had not yet lived in the married state for five years, 28 were still without family; and in BURKE'S 'Peerage,' for 1842, there still remained among these 28 marriages, 7 without issue, making 81 as the total number of unproductive marriages among the original 503; or the proportion of the unproductive to the productive marriages among this number is, as nearly as possible, 1 in $6\frac{3}{4}$. In the above calculation, I have excluded 8 unproductive marriages, in which the age of the husband at the date of marriage exceeded 56. These 8, however, ought to be deducted from the original sum of total marriages that were included; or, in other words, the 503 should be reduced to 495, and then the whole result would stand thus:—among 495 marriages in the British Peerage, 81 were unproductive, or 1 in $6\frac{1}{8}$ were without any family." The proportion of unproductive marriages in Grangemouth, Bathgate, and the British Peerage, all taken together, was found by SIMPSON to be 1 in $8\frac{1}{4}$.

Dr WEST* states, that he found the general average of sterile marriages, among his patients at St Bartholomew's Hospital, to be 1 sterile marriage in every 8·5.†

CHAPTER III.—*Absolute Sterility of Wives.*

In order to arrive at the absolute sterility of the wives in Edinburgh and Glasgow, it is necessary to add to the number of wives bearing first living children, the number of those who bear only dead children or abortions.

* Diseases of Women, 3d edition, p. 3.

† A statement of the sterility of Esquimaux women is given by ROBERTON, Essays and Notes on the Physiology and Diseases of Women, p. 53.

The number of abortions has been variously estimated by GRAUNT, SHORT, WHITEHEAD, and others. The number of children born dead has been the subject of much investigation, among others by JACQUEMIER, BOUDIN, and LEGOYT. But were our information on these points very exact, it would not help us in this inquiry. For our purpose, the desideratum is not the number of abortions in a number of pregnancies, nor the number of children born dead in a number of births, but the proportional number of married women who produce nought else than abortions or dead children; who, while not absolutely sterile, yet add none to the population. Of this class of wives I know of no estimate.* I believe they are few, and I leave the statement of the sterile as a near approximation to a correct statement of the absolutely sterile.

CHAPTER IV.—*Sterility according to the Ages of Wives.*

To illustrate the variations of sterility according to age, I bring forward the accompanying Table (I.).

TABLE I.—SHOWING THE VARIATIONS OF STERILITY ACCORDING TO THE AGES OF THE WIVES.

Ages of Wives at Marriage, ...	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50, &c.	Total.
Number of Wives, . .	700	1835	1120	402	205	110	46	29	4447
First Children, . . .	649	1905	809	251	96	10	2	...	3722
Sterile Wives, . . .	51	...	311	151	109	100	44	29	725
Percentage Sterile, . .	7·3	0	27·7	37·5	53·2	90·9	95·6	100	16·3
Proportion Sterile, 1 in	13·72	0	3·60	2·66	1·88	1·10	1·05	1·00	6·13

With the numbers of marriages taking place in Edinburgh and Glasgow in 1855, at different ages of the wives, are compared the numbers of first children born in the same year to wives married at the same ages in that year or previously. The number of sterile wives is got by subtracting the latter figures from the former, and the percentage of sterile marriages is given in the penultimate horizontal line.

So far as the numbers are to be relied upon, we have from this Table the interesting results, that about 7 per cent. of all the marriages between 15 and 19 years of age inclusive, and as they occur in our population, are without offspring; that those married at ages from 20 to 24 inclusive, are almost all fertile; and

* The following extract from the work of Dr WEST, on Diseases of Women (3d edit., p. 367), may be of some value. It refers to the histories of a set of poor women labouring under uterine cancer. "There were but two out of the whole 150 women, whose pregnancy had issued merely in abortion."

that, after that age, sterility gradually increases according to the greater age at the time of marriage.

Chapter V.—*Expectation of Sterility.*

The main element in the expectation of sterility is the age of the woman at marriage. This has just been described. But, besides this, our statistics suggest to us other laws as to the expectation of sterility. Of these the first is:—

That the probability of a woman's being sterile is decided in 3 years of married life. For while a large number are fertile in each of the first three years of married life, only 7 per cent. of the fertile bear after 3 years of marriage, or about 1 in 13.

TABLE II.—Showing the Fertility of Mothers, of different Ages at Marriage, commencing after Three Years of Married Life.

Mother's Age at Marriage, .	15–19	20–24	25–29	30–34	35–39	40–44	45–49	Total.
Number of Fertile, . . .	649	1905	809	251	96	10	2	3722
Number commencing Fertility after being 3 years married,	63	119	62	27	15	1	...	287
Percentage commencing Fertility after being 3 years married, ...	9·7	6·2	7·7	10·7	15·6	10·0	...	7·7
or 1 in	10·3	16·0	13·0	9·3	6·4	10·0	...	13·0

This same Table affords us a second law of expectation of sterility:—

That when the expectation of fertility is greatest, the probability of sterility is soonest decided, and vice versa. For our Tables show that of the wives married from 20 to 24 who are all fertile, only 6·2 per cent. begin to breed after three years of marriage; while at the other ages, with less fecundity, a greater percentage commences after the completion of the third year of marriage.

Chapter VI.—*Relative Sterility.*

Here I take into consideration only those who have borne children, only those who are not sterile. Of course all these wives, if they survive in wedlock, will sooner or later become relatively sterile. Now, in a paper lately read to this Society, I showed that the prolongation of fertility was greater according as the age at marriage was less. From this conclusion it is easy to derive one in regard to relative sterility, to the effect that:—

Relative sterility will sooner arrive according as the age at marriage is greater.

The demonstration of these proportions is arrived at by showing the proportional numbers bearing at different years of married life, according to age at marriage. This is an indirect way of proceeding, but it is the only one I can find available, while I have no documents giving the ages of mothers at marriage, and their ages at birth of last children, the mothers continuing to live in wedlock.

TABLE III.—SHOWING THE RELATIVE STERILITY OF A MASS OF WIVES MARRIED AT DIFFERENT AGES AT SUCCEEDING EPOCHS IN MARRIED LIFE.

Age of Mother at Marriage, ...	15–19	20–24	25–29	30–34	35–39	Total.
Proportion Sterile about the 5th Year of Married Life is about 1 in	2·78	2·61	1·68	1·51	1·19	2·09
or a percentage of	35·9	38·3	59·4	66·0	84·1	47·9
Proportion Sterile about the 10th Year of Married Life is about 1 in	2·09	1·71	1·39	1·24	...	1·61
or a percentage of	47·9	58·3	71·8	80·8	...	62·1
Proportion Sterile about the 15th Year of Married Life is about 1 in	1·57	1·32	1·10	1·05	...	1·26
or a percentage of	63·8	75·5	90·9	95·5	...	79·2
Proportion Sterile about the 20th Year of Married Life is about 1 in	1·24	1·13	1·01	...	...	1·11
or a percentage of	80·4	88·6	98·7	...	...	89·8
Proportion Sterile about the 25th Year of Married Life is about 1 in	1·02	1·00	...	...	...	1·01
or a percentage of	97·6	99·65	...	...	...	99 03

Table III. gives the calculated amounts of sterility at different periods of married life in women married at different ages. It is needless to enter on the method of construction of this Table. It is merely the complement of Table XV., given in my former paper, where full details are stated. I shall only state, that this Table is all calculated for 20 months, with a view to giving the nearest accurate estimate, 20 months being what I have called the time-unit of fertility, the shortest time within which all women may be expected to show fertility if they possess it.

CHAPTER VII.—*Expectation of Relative Sterility.*

As a sort of appendix to this paper, I produce five Tables, giving all the details of the expectation of continued fertility; and conversely, of relative sterility. These Tables not only give data for calculating the chances of relative sterility, but also for calculating the probable number of the family produced in women at different ages becoming relatively sterile. To enter further upon these

considerations would be merely to give in writing what is more succinctly stated in the Tables themselves.

TABLE IV.—Fifth Year of Married Life.

Number of Child, ...	1st	2d	3rd	4th	5th	6th	7th	8th	9th	Total.
Wives Mothers, of Ages 20–24, .	13	39	160	31	4	...	...	...	...	247
Proportion of above to 644 Wives Married at from 15–19 is 1 in	49·5	16·5	4·0	20·8	161·0	...	..	...	...	2·6
Wives Mothers, of Ages 25–29, .	10	82	398	106	13	2	...	...	...	611
Proportion of above to 1686 Wives Married at from 20–24 is 1 in	168·6	20·5	4·2	15·9	13·0	843·0	...	...	...	2·7
Wives Mothers, of Ages 30–34, .	3	31	147	52	8	2	1	...	...	244
Proportion of above to 1008 Wives Married at from 25–29 is 1 in	336·0	32·5	6·8	19·4	126·0	504·0	1008	...	...	4·1
Wives Mothers, of Ages 35–39, .	3	12	37	14	1	1	2	1	1	72
Proportion of above to 358 Wives Married at from 30–34 is 1 in	119·3	29·8	9·7	25·6	358·	358·	179·	358·	358·	4·9
Wives Mothers, of Ages 40–44, .	3	2	11	1	...	...	...	...	...	17
Proportion of above to 179 Wives Married at from 35–39 is 1 in	59·6	89·5	16·3	179·	...	...	...	...	...	10·5
Total Wives Mothers, of Ages 20–44,	32	166	753	204	26	5	3	1	1	1191
Proportion of above to 3875 Wives Married at from 15–39 is 1 in	121·1	23·3	5·1	19·0	149·	775·	1291·6	3875·	3875·	3·2

Lastly, I state a law of relative sterility for which I do not here adduce the numerical proofs, these having already been given in my paper lately read to the Society. This law is, that:—

A wife who having had children, has ceased for three years to exhibit fertility, has probably become relatively sterile; that is, will probably bear no more children; and the probability increases as time elapses. For the probability of sterility only commences after three years of sterile marriage. Further, the data given in Table II. of the paper just referred to, show that fertile women bear a child, on an average, about every two years, so long as they remain fecund. The data given in Table VI. show that successive children in a family succeed one another with an average interval of about 20 months. To these propositions I have to add the general consent, shown in the same paper, that fertile wives breed generally every two years; consequently, that no class breeds, though individuals do, at shorter intervals; and no class breeds at longer intervals, though individuals do so. Considering these different statements, it is apparent to the student, that there is no room left for any but a very inconsiderable number of women to breed at longer intervals than two years. For were there any con-

siderable number of wives breeding at longer intervals, the averages just given would be far overpassed. And some of these averages are, as already shown, considerably less than were believed to be the true averages by writers who were not thinking of the law now demonstrated, but of the ordinary rate of time-fertility of married women.

Besides, being of evident intrinsic value, the conclusions arrived at in this paper will afford to medical men, means of estimating the utility of the many vaunted methods of curing sterility which are now much in vogue, and which, considering the nature of the condition to be cured, justly excite anxiety for the honour of the profession in the minds of its best friends.

TABLE V.—Tenth Year of Married Life.

Number of Child, .	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	Total.
Wives Mothers, of Ages 25–29, .	...	1	14	30	78	51	8	4	...	...	...	186
Proportion of above to 594 Wives Married at from 15–19 is 1 in	...	594·	42·4	19·8	7·6	11·6	74·2	148·5	...	...	...	3·2
Wives Mothers, of Ages 30–34, .	1	4	17	55	148	105	34	11	3	1	2	381
Proportion of above to 1528 Wives Married at from 20–24 is 1 in	1528·	382·	89·9	27·8	10·3	14·5	44·9	138·9	509·3	1528·	764·	4·0
Wives Mothers, of Ages 35–39, ,	...	2	4	19	60	48	13	5	2	...	...	153
Proportion of above to 902 Wives Married at from 25–29 is 1 in	...	451·	225·5	47·5	15·	18·8	69·4	180·4	451·	...	...	5·9
Wives Mothers, of Ages 40–44, .	...	...	5	11	10	6	2	1	...	1	...	36
Proportion of above to 313 Wives Married at from 30–34 is 1 in	...	...	62·6	28·5	31·3	52·2	156·5	313·	...	313·	...	8·7
Total Wives Mothers, of Ages 25–44, .	1	7	40	115	296	210	57	21	5	2	2	756
Proportion of above to 3337 Wives Married at from 15–34 is 1 in	3337·	476·7	83·4	29·0	11·3	15·9	58·5	158·9	667·4	1668·5	1668·5	4·4

TABLE VI.—Fifteenth Year of Married Life.

Number of Child, . .	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	Total
Wives Mothers, of Ages 30–34, . .	1	3	2	6	11	18	24	28	18	2	1	1	1	116
Proportion of above to 532 Wives Married at from 15–19 is 1 in	532·	177·3	266·	88·7	48·4	29·6	22·2	19·0	29·6	266·	532·	532·	532·	4·6
Wives Mothers, of Ages 35–39, . .	...	...	5	4	18	32	53	41	29	14	2	1	1	200
Proportion of above to 1360 Wives Married at from 20–24 is 1 in	...	...	272·	340·	75·5	42·5	25·6	33·2	46·9	97·1	680·	1360·	1360·	6·8
Wives Mothers, of Ages 40–44, . .	...	...	1	2	4	7	12	14	2	1	...	...	...	43
Proportion of above to 782 Wives Married at from 25–29 is 1 in	...	...	782·	391·	195·5	111·7	65·2	55·9	391·	782·	...	...	...	18·2
Wives Mothers, of Ages 45–49, . .	...	...	...	1	1	1	...	1	2	...	1	...	...	7
Proportion of above to 262 Wives Married at from 30–34 is 1 in	...	...	...	262·	262·	262·	...	262·	131·	...	262·	...	...	37·4
Total Wives Mothers, of Ages 30–49, . .	1	3	8	13	34	58	89	84	51	17	4	2	2	366
Proportion of above to 2936 Wives Married at from 15–34 is 1 in	2936·	978·6	367·	225·8	86·3	50·6	33·0	34·9	57·5	172·7	734·	1468·	1468·	8·0

TABLE VII.—Twentieth Year of Married Life.

Number of Child, . .	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	Total.
Wives Mothers, of Ages 35–39, ...	...	...	2	5	5	17	15	9	3	...	56
Proportion of above to 477 Wives Married at from 15–19 is 1 in	...	...	238·5	95·4	95·4	28·0	31·8	53·	159·	...	8·5
Wives Mothers, of Ages 40–44, ...	1	1	2	9	14	28	8	13	2	2	80
Proportion of above to 1171 Wives Married at from 20–24 is 1 in	1171·	1171·	585·5	130·	83·6	41·8	146·4	90·1	585·5	585·5	14·6
Wives Mothers, of Ages 45–49, ...	...	...	...	...	...	3	...	1	1	...	5
Proportion of above to 649 Wives Married at from 25–29 is 1 in	...	...	...	...	...	216·3	...	649	649	...	129·8
Total Wives Mothers, of Ages 35–49, .	1	1	4	14	19	48	23	23	6	2	141
Proportion of above to 2297 Wives Married at from 15–29 is 1 in	2297·	2297·	574·2	164·	121·	47·8	99·9	99·9	383·	1148·	16·3

TABLE VIII.—Twenty-Fifth Year of Married Life.

No. of Child, ...	10th	11th	12th	13th	14th	15th	16th	17th	Total.
Wives Mothers, of Ages 40–44,	2	2	1	1	...	...	...	...	6
Proportion of above to 408 Wives Married at from 15–19,	204·	204·	408·	408·	...	...	...	...	68·
Wives Mothers, of Ages 45–49,	...	1	...	...	...	...	...	1	2
Proportion of above to 961 Wives Married at from 20–24,	...	961·	...	...	...	...	...	961·	480·5
Total Wives Mothers, of Ages 40–49, ...	2	3	1	1	...	...	...	1	8
Proportion of above to 1369 Wives Married at from 15–24,	684·	456·	1369·	1369·	...	...	...	1369·	171·

XXIV.—*On a New Property of the Retina.* By Sir David Brewster, K.H., D.C.L., F.R.S., &c.

(Read 19th February 1866.)

In a paper on Hemiopsy, published in the present volume of the Transactions (p. 15), I have mentioned the remarkable fact, that the parts of the retina which are insensible to visual, are sensible to luminous impressions, the light being occasioned by irradiation from the adjacent parts of the retina. The parts thus affected in hemiopsy extend irregularly from the *foramen centrale* to the margin of the retina; but the space which they occupy is so small, their distribution so irregular, and the time of their continuance so short, that it is difficult to make such observations upon them as would establish a general property of the retina.

Mr Airy, our distinguished Astronomer-Royal, who has had more than twenty attacks of hemiopsy, has been induced, by the perusal of my paper, to describe their character, and delineate the form of the parts insensible to visual impressions.* The hemiopsy, in his case, commences at the *foramen centrale* c, Fig. 1, and extends outwards in a zig-zag curve line, the curve "being small at first, and gradually increasing in dimensions," as shown in the figure. It is accompanied with "tremor and boiling so oppressive, that if produced only in one eye, they may nearly extinguish the corresponding vision in the other," and it lasts from twenty to thirty minutes. It occurs sometimes on one side, and sometimes on the other side, of the foramen; and Mr Airy has "never been able to decide with certainty whether the disease really affects both eyes." On one occasion, when under its influence, he lost "his usual command of speech, and his memory failed so much that he did not know what he had said, or had attempted to say, and that he might be talking incoherently." He, therefore, entertained "no doubt that the seat of the disease was in the brain; that the disease is a species of paralysis; and that the ocular affection is only a secondary symptom."

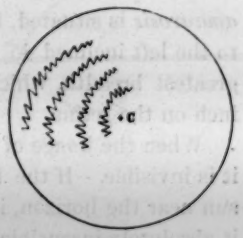


Fig. 1.

From these important facts, it will be seen that Mr Airy's case differs essentially from mine, in which the locality of the indistinctness occurs in irregular

* Philosophical Magazine, July 1865, vol. xxx. p. 19.

zig-zag lines proceeding, as in Fig. 2, from the foramen outwards, and not in a circular arch, as shown in Fig 1. The "general obscuration," mentioned by Mr AIRY, shows that the luminous impression on the affected parts is not so strong in his case as in mine, and that the retina is still sensible to light derived from the surrounding parts by irradiation. The severity of the affection in Mr AIRY's case is remarkable. In mine the attack is little more than disagreeable, and I have never experienced the slightest effect either upon the speech or the memory. I have given this brief abstract of Mr AIRY's interesting paper from the relation of hemiopsy to the permanent affection of the retina which I am about to describe.



Fig. 2.

When without the hope of obtaining any precise information respecting the irradiation into the parts of the retina affected with hemiopsy, an accidental observation revealed to me the disagreeable fact that a considerable portion of the retina of my right eye was absolutely blind, or insensible to visual impressions; and I have thus been enabled, from the extent and permanence of the affection, to make whatever observations were necessary to ascertain the true character of the phenomenon.

The portion of the retina thus affected with what may be called *local amaurosis* is situated, in the field of vision, about 15° from the foramen, in a line to the left inclined 45° to the horizon. Its angular magnitude is about 6° in its greatest breadth, which corresponds to a space about the twenty-eighth of an inch on the retina.

When the image of a bright object covers the whole, or any part of this spot, it is invisible. If the image is the flame of a candle, or of the moon, or of the sun near the horizon, it is wholly invisible. The eye is therefore at this part of it absolutely insensible to light falling upon it from without. If we now direct the eye to the sky, to the white ceiling of a room, or to any extended white surface, no dark spot, even of the slightest shade, is seen in the field of vision. The portion of the retina, therefore, insensible to light incident upon it directly, or from without, has been illuminated by irradiation from the surrounding parts. But for this wise provision, an eye affected with local amaurosis would carry about with it a black spot, disfiguring the aspects of nature, and ever reminding the patient of his misfortune.

How long this condition of my retina has existed, I cannot discover. It may have existed for half a century, or more; and, but for a casual observation, its existence might never have been discovered. Whether it came on gradually, or was produced in some of the experiments in which the eye was exposed to the light of the sun, I have no means of ascertaining. If from the first of these

causes, it is likely to extend itself; if from the second, it may remain as it is. Having observed it only for a year without noticing any enlargement, it is probable that it was produced by the strong action of light.

Owing to the compound structure of the retina, consisting of different layers, and these layers composed of bodies of different shapes, it is very difficult to discover the part which each of them performs in the act of vision; but considering each element of the retina as a *rod*, the end of which next the vitreous humour is an expansion of the optic nerve, we know that distinct vision of external objects arises from the law of visible direction, by which every ray of light, at whatever angle it may fall, gives us vision of the point from which it proceeds, in a direction perpendicular to the part of the membrane on which it is incident. When this outer layer of the retina is insensible to the light of external objects, its luminosity, or the light which it exhibits, may be received from the surrounding parts of the expanded nerve by irradiation, or from the parts of the elemental rods behind it, if they were not paralysed, or if they are, by the action of the unparalysed rods around them.

Although in hemiopsy, and in the case of local amaurosis which I have described, the paralysed parts are still luminous, yet there are cases in which these parts are absolutely black, and into which no light is introduced by irradiation. An example of this fact presented itself to me in the morning of the 16th October 1837, and is represented in Fig. 3, where two black curved lines proceeded from the *foramen centrale* of the retina of the right eye. These lines were so black that, in the memorandum which I made at the time, I state that they were blacker than the black ink lines upon the paper. The lines continued only about *ten* minutes, and were probably produced by the pressure of blood-vessels, as I had, the day before, been subject to much giddiness. In this case, the elementary rods of the retina beneath these lines must have been paralysed throughout their length; and, therefore, it is probable that in the cases of hemiopsy and local amaurosis, the paralysis affects only the end of the rods in contact with the vitreous humour, and formed by the expansion of the optic nerve.



Fig. 3.

In concluding this notice, I would suggest to philosophers and medical practitioners the importance of studying the manner in which sight and hearing are, in their own case, gradually impaired, for it is in the decay or decomposition of organic structures, as well as in their origin and growth, that valuable results may be presented to the physiologist; and facts of this kind have a peculiar value when the patient is himself a practised observer.

XXV.—*On the Classification of Chemical Substances, by means of Generic Radicals.* By Alexander Crum Brown, M.D., D.Sc.

(Read 5th February 1866.)

The idea of chemical structure, as founded on that of atomicity (or the equivalence of atoms), enables us to divide any molecule, whose chemical structure is known, into radicals. The number of ways in which this may be done increases with the complexity of the molecule. Each of these modes of division corresponds to a series of conceivable reactions, some of which have been observed. Any one of these series may be made the basis of classification; but it is obviously most convenient to select for this purpose the most characteristic reactions, and those which are common to such substances as form natural groups. In studying these, we find that each series implies the presence of a particular radical, within which the reactions in question take place. We may call such series of reactions the Generic reactions, and the corresponding radicals Generic radicals. These are sometimes residues of double decomposition, but very frequently this is not the case, and this may account for the fact, that the importance of these generic radicals has been very much overlooked.

I shall consider some of the cases in which this principle of classification is already, to some extent, recognised, before proceeding to apply it generally, and examine first those examples furnished by groups of bodies which are referred to the types H_2O and NH_3.

I. A large number of the substances referred to the type H_2O, are formed by the replacement of *one* atom of H in each molecule of H_2O, by a radical, as,—

$$\left.\begin{matrix}K\\H\end{matrix}\right\}O, \qquad \left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O, \qquad \left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O, \qquad \left.\begin{matrix}H\\C_2H_4\\H\end{matrix}\right\}O \qquad \left.\begin{matrix}H\\SO_2\\H\end{matrix}\right\}O, \quad \&c.$$

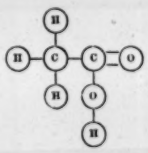
The part common to all such bodies is the radical $(HO)'$ or $\left.\begin{matrix}\cdot\\H\end{matrix}\right\}O$, and the reactions common to the group affect this radical alone. These reactions are—1*st*, The replacement of $(HO)'$; 2*d*, The replacement of H in $(HO)'$; and 3*d*, The replacement of O in $(HO)'$. Thus (HO) may be replaced by Cl, Br, &c., or $(HO)_2$ by O; $(HO)'$ may become $(KO)'$, $(C_2H_5O)'$, &c. by the replacement of H, or $(HS)'$, $(HSO_4)'$, &c. by replacement of O. $(HO)'$ is therefore the generic radical of this large genus.

II. An extensive series of substances referrible to the type NH_3 have only *one* atom of H in each molecule of ammonia replaced.

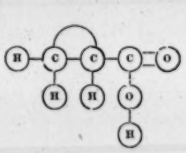
As $\left.\begin{matrix}C_2H_5\\H_2\end{matrix}\right\}N$, $\left.\begin{matrix}C_2H_3O\\H_2\end{matrix}\right\}N$, $\left.\begin{matrix}C_2H_3O_2\\H_2\end{matrix}\right\}N$, $\left.\begin{matrix}H_2\\C_2H_4\\H_2\end{matrix}\right\}N$ $\left.\begin{matrix}H_2\\C_2O_2\\H_2\end{matrix}\right\}N$, &c.

In these we have $(NH_2)'$, or $\left.\begin{matrix}\cdot\\H_2\end{matrix}\right\}N$ common to the group. The generic reactions are—1*st*, Replacement of one or both atoms of H in NH_2 by radicals. 2*d*, The addition of two monatomic atoms to each NH_2, N''' becoming N^v. 3*d*, The replacement of N''' by O'' and $(HO)'$ (by the action of nitrous acid), or what comes to the same thing, the replacement of NH_2 by HO. All these affect the radical NH_2 alone, which is therefore the generic radical. In the same way $(NH)''$ is the generic radical of the substances derived from ammonia, by the replacement of two atoms of H.

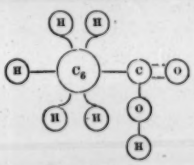
The best way of extending this method of classification generally, is to examine the chemical structure of those bodies which form well-marked genera, and see what group of atoms they have in common, and whether the common group (or radical) is that part of the molecule, in which the reactions characteristic of the genus take place. One very well-marked genus is that of the monobasic acids, which have aldehydes and alcohols corresponding to them (KOLBE'S "Monocarbonsäuren"). As examples, we may take acetic acid, acrylic acid, benzoic acid, and cinnamic acid. The chemical structure of these substances is represented, as far as known, by the following graphic formulæ:—



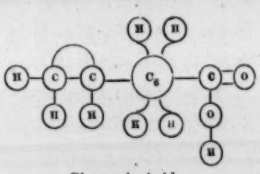
Acetic Acid.



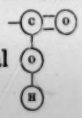
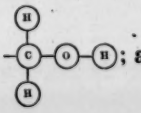
Acrylic Acid.



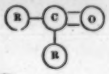
Benzoic Acid.

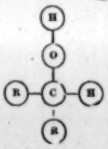


Cinnamic Acid.

The part common to all these acids is obviously the monatomic radical  and the generic reactions take place within it; the salts are formed by the replacement of the H by metal,—chlorides, bromides, aldehydes, &c., by the replacement of the $(HO)'$, by Cl, Br, H, &c.; alcohols from the aldehydes, by the addition of H_2  becoming  ; amides, by the replacement of $(HO)'$ by NH_2; nitriles, by the replacement of O'' and $(HO)'$ by N'''; acetones, from two molecules, by the loss of CO(HO) in one, and the substitution of the radical thus produced for HO in the other. $\{(CO(HO)\}'$ is, then, the generic radical of these acids. As this radical is of very great importance, it is advisible to indi-

cate it by a single symbol, and I shall use the Greek letter Ξ for this purpose.* The relation of Ξ to CN, or of the acid to the nitrile, is seen not only in the monobasic acids (monocarbonsäuren), but also in the di- and tri-basic acids (di- and tricarbonsäuren), so that these contain the radical Ξ, two and three times respectively.

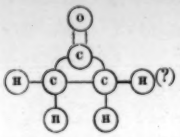
The investigation sketched above also shows that COH and $CH_2(HO)$, are the radicals of the aldehydes and the "true" alcohols. Pursuing this method further, we arrive at a system of classification for the various groups of pseudo-alcohols, the number of which has recently increased so much. One of these groups is formed by the hydrogenation of the acetones. The acetones have the general formula COR_2 (in which R_2 may represent either two atoms of the same or of two different radicals); taking the graphic formula, we have 

( being the generic radical), by the addition of H_2, we get  the

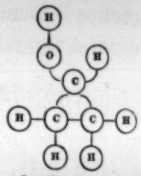
reaction being similar to that by which the aldehydes are converted into true alcohols, one of the two pairs of equivalents by which the O atom is united to the C, being separated, and hydrogen added to each of the equivalents (one of O and one of C), thus rendered free. The generic radical here is obviously $\{CH(HO)\}''$, and the subgenera and individual substances are determined by the radicals saturating the two free equivalents of this generic radical. This genus, besides the universal character of the alcohol family (the formation of ethers) has the property of forming aldehydic bodies (acetones) by the loss of two atoms of H, $\{CH(HO)\}''$ becoming $(CO)''$; and in that subgenus which contains the radical $\{CH_2(HO)\}'$ (or in which one of the R's is H), this aldehydic body is a true aldehyde, capable of forming an acid by further oxidation. When none of the equivalents of the carbon atom in the generic radical are directly saturated with H, the alcohol is incapable of producing an aldehyde or acetone; and, in this case, we have the characteristic radical reduced to $\{C(HO)\}'''$, as in BUTLEROW's trimethyl alcohol. We thus see that the most general form of alcohol is $C(HO)R_3$ (where R_3 represents one triatomic, or one diatomic and one monatomic, or three monatomic radicals); and the genera, sub-genera, and individuals of this family are determined by the nature of the radical or radicals, combined with the family radical $\{C(HO)\}'''$. For convenience let us, in the meantime, represent this radical by the symbol Φ'''. The different subdivisions of the family will then be $R'''\Phi$, $R''R'\Phi$, and $R'_3\Phi$. If

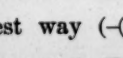
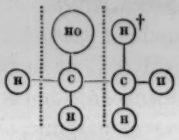
* I had proposed to express the radical (COHO)' by the symbol Ξ, before I was aware that BUTLEROW had already used the symbol A to represent the same radical. While fully acknowledging the priority of BUTLEROW's recognition of this radical, I prefer to retain the symbol Ξ. By using such of the Greek capitals as differ from the Roman in form, to represent generic radicals, we avoid the danger of confounding them with elementary atoms.

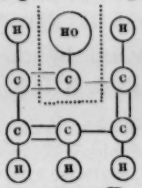
the original and ingenious speculations of KEKULÉ on the constitution of the aromatic bodies should be experimentally confirmed, phenylic alcohol would be an example of the first form $(C_5H_5)'''\Phi$.* The second and third form may be subdivided into genera, having the generic radicals $(R'\Phi)''$. As we have seen, by far the most important of these is that containing $H\Phi$, and it may be convenient to express this by a separate symbol, say Θ''. Under this genus we have two forms, $R''\Theta$ and $R'_2\Theta$. The so-called ketones of the dibasic carbon acids (dicarbonsäuren) may be regarded as the aldehydes of unknown alcohols of the first form; thus succinone



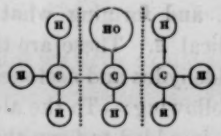
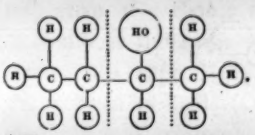
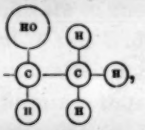
may be considered as the aldehyde of the unknown alcohol, ...

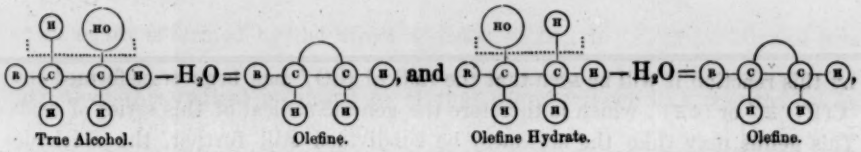


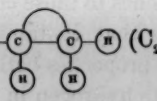
To the second form $R'_2\Theta$, belong the greater number of known alcohols, and a considerable number of bodies possessing alcoholic properties, though not generally classified with the alcohols. They form aldehydes or acetones by oxidation; and this reaction is not confined to those substances to which the name alcohol is commonly applied: for instance, mesoxalic acid is the aldehyde (or acetone) of tartronic acid, alloxan that of dialuric acid, glyoxylic acid that of glycollic acid. Confining our attention to those substances of the form $R'_2\Theta$, in which R is of the form $(C_nH_{2n+1})'$, and has its C atoms arranged in the simplest way  , &c.), we may form the following series of sub-generic radicals $H\Theta$, $CH_3\Theta$, $C_2H_5\Theta$, &c. The first of these we have seen to be the radical of the "true" alcohols, and it seems probable that the second is that of the hydrates of the olefines. The arguments in favour of this view (which undoubtedly requires and admits of further experimental research) may be stated thus:—The first member of the series, the hydrate of ethylene, is identical with common alcohol, and has the formula  or, $\left.\begin{matrix}CH_3\\H\end{matrix}\right\}\Theta$. The

* Translating KEKULÉ's graphic formula for phenylic alcohol into the system used in this paper, we have  in which we have the triatomic radical C(HO) united to the triatomic radical C_5H_5.

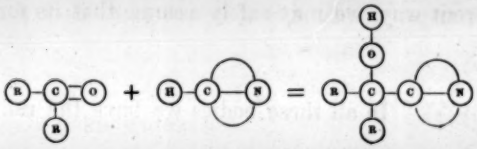
† Using the symbol as a contraction for .

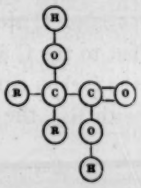
hydrate of propylene is almost certainly identical with the alcohol derived from acetone, which is  or $\left.\begin{matrix}CH_3\\CH_3\end{matrix}\right\}\Theta$. The constitution of hydrate of butylene has not been directly ascertained, but as it is obviously *meta*meric with butylic alcohol, and as it is in the highest degree improbable that its C atoms are arranged in a different way, we may safely assume that its formula is $\left.\begin{matrix}CH_3\\C\,H_5\end{matrix}\right\}\Theta$,  . In all these bodies we have the radical  , $\left.\begin{matrix}CH_3\end{matrix}\right\}\Theta$, and from the similarity of the method by which the others are produced, it is reasonable to infer that they are similarly constituted. If so, while the "true" alcohols have the water residue united to what we may call a *terminal* C atom, the olefine hydrates have the water residue united, not to this, but to the C atom next to it. As both alcohols give the olefine by dehydration, the carbon equivalents deprived of HO and H, must be those which are combined with HO, the one in the one, and the other in the other. Thus:—



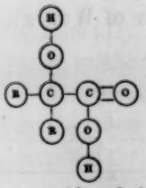
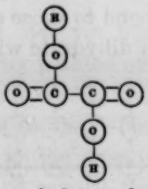
So that  $(C_2H_3)'$ must be the generic radical of the olefines. As the true alcohols are formed from the aldehydes, or, as they may be called, the formo-ketones (as produced by distilling a mixture of formiate of lime with another lime salt), so we may presume that the alcohols $\left.\begin{matrix}CH_3\\R\end{matrix}\right\}\Theta$, may be produced from the aceto-ketones (the ketones formed by distilling acetate of lime with other lime salts), and the same is no doubt the case with all the other genera of pseudo-alcohols of the form $R'_2\Theta$. $(HCO)'$, $(CH_3CO)'$, $(C_2H_5CO)'$, &c., becoming $(H\Theta')$, $(CH_3\Theta)'$, $(C_2H_5\Theta)'$, &c. The same considerations would, of course, apply to other series besides that of completely saturated bodies, but it is unnecessary to do more than mention this as LINNEMANN's benzhydrol $(C_6H_5)_2\Theta$ stands, as yet, alone as a pseudo-alcohol of this class among non-saturated bodies.

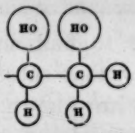
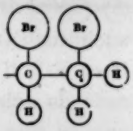
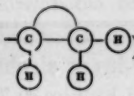
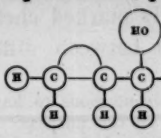
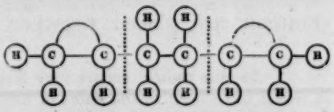
Derived from the aldehydes and acetones, we have another series of substances, having well-marked reactions in common, and forming what we may call a subgenus of the genus containing the radical Ξ. These are the acids obtained by the action of HCl and HCN, on the aldehydes and acetones. The mode of formation of these acids appears to be the following:—To the aldehyde or ketone HCN is first added in the same way as H_2 is added to form the alcohol, a body which may be called an *oxynitrile* being then produced.



(this stage of the reaction can be traced in the case of bitter almond-oil; the so-called hydrocyanate of bitter almond-oil being, no doubt, the nitrile of mandelic acid). In the second stage of the reaction this nitrile is decomposed (like other nitriles) by the HCl and water, yielding NH_4Cl, and the acid 

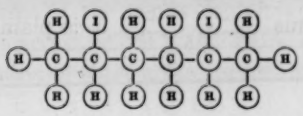
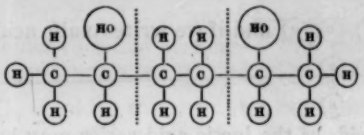
by this reaction it will be seen that the radical $(CO)''$ has been transformed into $(C(HO)\Xi)''$ or $(\Phi\Xi)''$, which is therefore the generic radical of this series of acids. This genus may (like the acetones) be subdivided still further, the aldehydes giving rise to acids containing $(\Phi H\Xi)'$ (or $\Theta\Xi$), the acetoketones to those containing $(\Phi CH_2\Xi)'$, &c. The best known of these subdivisions is that containing $(\Theta\Xi)'$. As indicated by the generic radical, these bodies have the properties both of acids and alcohols, giving rise to salts by the replacement of the hydrogen in the Ξ by metals, and to ethers by the replacement of the (HO) in the Θ by salt radicals (acids minus H). Some of them, at least, seem capable of forming aldehydes; for, as DEBUS has pointed out, glyoxylic acid is the aldehyde of glycollic acid. (It is worthy of note, that glycollic acid is the only member of the series which is a "true" alcohol, containing the radical $(H\Theta)'$, and giving rise, by oxidation, to an aldehyde and an acid—glyoxylic and oxalic acids). The typical formulæ of FRANKLAND and DUPPA indicate in a different way the same constitution as that expressed by the radical formulæ above; $C_2\begin{cases} O'' \\ HO \\ HO \\ R_2 \end{cases}$ being obviously identical with

 and if we write oxalic acid $(\Xi)_2$, thus  it is plain that the acids of the lactic acid series may be derived from it by replacing O″ by R_2.

KOLBE long ago suggested, and MAXWELL SIMPSON has since proved, that the dibasic and tribasic carbon acids are related to two and three molecules respective of carbonic acid, in the same way as the monobasic acids are to one molecule of the same substance. They therefore contain the radical Ξ two and three times respectively. Similarly, we might expect to find bodies containing the derived radicals (COH), (CH_2HO), &c., two or three times, forming thus diatomic and triatomic aldehydes, alcohols, &c. We only know one diatomic aldehyde, glyoxal $(COH)_2$, and with certainty, only one diatomic *true* alcohol, glycol $(CH_2HO)_2$. From the way in which the other glycols are formed, it will be seen, that if the view of the structure of the olefines suggested above be correct, they contain the radical  (formed by replacing Br by HO in  which again is formed by the direct addition of Br_2, to ), and it is only when this radical is united to H that the glycol can be a *true* alcohol *on both sides*. Taking this view, propylenic glycol is a compound of the radicals $(H\Theta)'$, and $(CH_3\Theta)'$; amylenic glycol of $(H\Theta)'$ and $(C_5H_7\Theta)'$, and so of the others, one of the atoms of water residue being in the position of the HO in a true alcohol, the other in that of an olefine-hydrate. Of course, it is quite conceivable, and indeed very likely, that there are bodies which contain the radical (CH_2HO) twice or oftner, and are thus polyatomic *true* alcohols; but, with the exception of ethylenic glycol, they are as yet unknown. In treating of diatomic alcohols, we cannot pass over the curious body obtained by WURTZ, by the addition of water to allyl. A consideration of the chemical relations of acrylic acid, acrolein and allylic alcohol to propionic acid, propionic aldehyde and propylic alcohol indicates for allylic alcohol the formula  and for allyl 

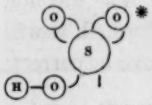
It is therefore a diatomic olefine, containing the radical $(C_3H_5)'$ twice, and if its

reactions correspond to those of the monatomic olefines the formulæ of WURTZ's, dihydriodate and dihydrate will be,—


and


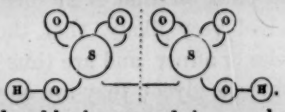
the latter will thus contain the radical $(CH_3\Theta)'$ twice, and be a diatomic olefine-hydrate.

The organic acids derived from sulphuric acid, and which are formed by the addition of SO_3 to organic substances containing hydrogen, stand in the same relation to sulphuric acid as the carbon acids (carbonsäuren) do to carbonic acid; in these we have an organic radical replacing one HO in $SO_2(HO)_2$. They therefore contain the radical $SO_2(HO)$; which, assuming the hexatomic character of the sulphur atom in sulphuric acid, may be represented by the graphic formula,



As we have numerous generic radicals derived from $\{(CO)\,HO\}'$ such as COH, $CH_2(HO)$, we might expect to find similar derived radicals from $SO_2(HO)$, and there can be little doubt that substances containing such radicals exist; but as yet very few of them are known. Thus we have only one or two substances corresponding to the acetones, such as sulpho-benzid, $(C_6H_5)_2SO_2$; a few chlorides containing SO_2Cl, but no bodies corresponding to the aldehydes or alcohols.† The remarkable substance discovered by V. OEFELE, and named by him "Triæthyl sulphin oxydhydrat," and which has the formula $S^{iv}(C_2H_5)_3(HO)$, is a proof of the possibility of such bodies. This substance has the same relation to sulphurous acid that BUTLEROW's trimethyl alcohol has to carbonic acid.

As the radical COHO unites with itself to form oxalic acid, so we have SO_2HO, forming hyposulphuric acid $(SO_2HO)_2$



The examples of generic radicals might be considerably increased in number, but as the purpose of this paper is not so much to tabulate known substances, as to show how this may be done, those given above may suffice. It will be seen that by this method, bodies having strongly marked chemical reactions in common are placed together. The relations between different genera are

* As this radical occurs very frequently, it may be advantageous to have a single symbol for it, and I have been in the habit of using the Greek letter Σ for this purpose. Thus we have $CH_3\Sigma$ acetic acid; $CH_3\Sigma$ methylsulphuric acid; $CH_2\Sigma\Sigma$ sulphacetic acid, &c.

† See KOLBÉ, Lehrbuch der Organischen Chemie, Bd. ii. s. 742.

prominently brought forward, and the vacancies, not yet filled up by experiment, in the list of conceivable compounds, distinctly pointed out.

The division of molecules into two parts, one more readily undergoing chemical change than the other, presents certain analogies to the "Theory of Copulæ," proposed by BERZELIUS. This is most marked in the case of the acids containing $(COHO)'$ and $(SO_2HO)'$. On the theory of copulæ, these acids contain oxalic acid C_2O_3, H_2O, or hyposulphuric acid S_2O_5, H_2O, and a copula. Thus acetic acid was considered as C_2H_6, C_2O_3, H_2O, sulpho-benzolic acid as $C_{12}H_{10}$, S_2O_5, H_2O, &c.; according to the view which is taken in this paper, acetic acid contains the *half* of C_2H_6 (methyl), and the *half* of oxalic acid; sulpho-benzolic acid, the *half* of $C_{12}H_{10}$ (phenyl), and the *half* of hyposulphuric acid. In the same way, the older chemists regarded hydrochloric acid as H_2Cl_2, a compound of the *molecule* H_2, with the *molecule* Cl_2, while we now consider it as containing the *halves* of these molecules. It is therefore as correct to say, that acetic acid is a compound of methyl and oxalic acid, as that hydrochloric acid is a compound of hydrogen and chlorine. To prevent confusion, it is however better, whenever it can be done, to have separate names for the *radical* and the *substance*. Thus we may call $(COHO)'$ *Carboxyl* (as proposed by BAYER), and distinguish it from $(COHO)_2$ oxalic acid, $(SO_2HO)'$ might be called *Sulphoxyl*, and thus be distinguished from $(SO_2HO)_2$ hyposulphuric acid. Even in the case of those radicals whose names are the same as the isomeric substances, we may, in some instances, make the distinction; thus $(CH_3)'$ is methyl, $(CH_3)_2$ methyl gas, $(CN)'$ cyanogen, $(CN)_2$ cyanogen gas, Cl' chlorine, Cl_2 chlorine gas.

In conclusion, it may be interesting to enumerate some of those substances which consist *entirely* of generic radicals—all of whose reactions are therefore generic reactions—thus we have cyanogen gas $(CN)_2$, consisting of two atoms of the generic radical of the nitriles united together; glyoxal $(COH)_2$; glycol $(CH_2HO)_2$, or $(\Theta H)_2$; oxalic acid $(COHO)_2$, or Ξ_2; hyposulphuric acid $(SO_2HO)_2$, or Σ_2,; tartaric acid (probably) $(CH(HO))_2$ $(COHO)_2$, or $(\Theta\Xi)_2$; glycolic acid (CH_2HO) $(COHO)$, or $(\Theta H)\Xi$; glyoxylic acid (COH) $(COHO)$, or $(COH)\Xi$; tartronic acid $CH(HO)$ $(COHO)_2$, or $\Theta\Xi_2$; glycerine (probably) $(CH_2HO)_2(CH(HO))$, or Θ $(\Theta H)_2$; glyceric acid (CH_2HO) $(CH(HO))$ $(COHO)$, or (ΘH) $(\Xi\Theta)$; mesoxalic acid (CO) $(COHO)_2$, or $CO\Xi_2$.

XXVI.—*Some Observations on Incubation.* By JOHN DAVY, M.D., F.R.S., Lond. and Edin.

(Read April 16, 1866.)

The observations which I have now the honour to submit to the Society were made chiefly with the intent to endeavour to ascertain whether, in the instance of the egg of the common fowl, that which may be presumed to be vital action can for a while be arrested, and yet be capable of renewal. Whilst this was the main object kept in view in conducting the trials, a secondary one was to observe, however cursorily, the changes which take place in the contents of the egg when vital development has been prevented.

Of the many experiments I have made, during a period of more than two years that my attention has been directed to the inquiry, I shall select those, the results of which were best defined, or were least ambiguous. Considering the obscurity of the subject, it seems best to give the particulars of each of the selected trials, though, in so doing, I have to fear that the details may prove tedious.

In all the trials, newly or recently laid eggs were put under the hen for incubation, with those which were the special subject of experiment.

I. *Of Unimpregnated Eggs.*

The trial with these was made as a preparatory measure in relation to those which were to follow.

Four eggs were selected, obtained from a hen that had been kept apart after her last sitting. Of these, three in their fresh state were put under a hen with eleven ordinary eggs; the fourth was left exposed to the air in a room, the temperature of which varied from about 60° to 65° Fahr. on the 15th June, the day they were placed for incubation.

No. 1 weighed 727·5 grs.	No. 3 weighed 801·6 grs.
2 ... 851·5 „	4 ... 843·4 „

On the 9th of July the eleven impregnated eggs were hatched, producing healthy chickens. The three unimpregnated were found to be little altered. Again weighed, the loss of each, per cent., was as follows:—

No. 1, ... 14·6 grs.	No. 3, ... 12·3 grs.
2, ... 13·7 „	4, ... 2·7 „

The three from under the hen sank in water. Each broken under water, yielded

a little air; that from No. 1 was found to consist of 20 of oxygen, 80 of azote; that from No. 2 was of like composition. In neither could any carbonic acid be detected by milk of lime.

The appearance and qualities of the contents of both these eggs were similar. The white and yolk were distinctly apart, each confined in its proper membrane. There was no unpleasant smell from either. The white was quite transparent, with a slight yellowish tinge; the yolks were of their natural colour, with here and there spots of a lighter colour on their surface. The chalazæ were readily detached. Neither white nor yolk, when triturated with hydrate of lime, gave off the slighest ammoniacal odour, nor showed more than a faint fume when brought near a rod dipped in hydrochloric acid, a fume but little stronger than when water was substituted. Under the microscope, the appearance of the yolk differed but little from that of the yolk of an ordinary egg fresh and impregnated.

The egg No. 3 was not now examined; it was kept exposed to the air, with No. 4. These, on the 16th of October, were found, on weighing, to have sustained an additional loss—No. 3 of 9·6 per cent., No. 4 of 8·7; and on the 23d of November, when again weighed, of a further loss—No. 3 of 2·5 per cent., No 4 of 3·4.

Broken under water, No. 3 gave off a good deal of air of an offensive smell, that of sulphuretted hydrogen predominating. A portion collected was found to consist of 15 per cent., absorbable by milk of lime, chiefly carbonic acid, and of 85 not diminished by phosphorus, chiefly, if not entirely, azote. The contents of this egg were much changed: there was no distinct yolk or white, but a semifluid mixture of a whitish milky hue, partly curdled, with which were intermixed gelatiniform greenish masses, which, under the microscope, appeared to consist of cells and granules, the former suggestive of a kind of mucedo.

No. 4, broken under water, yielded a good deal of air, which had no odour, and which, on examination, was found to consist of about 20 per cent. oxygen and 80 azote, without any appreciable quantity of carbonic acid. The contents of the egg were hardly perceptibly altered; as of Nos. 1 and 2 the white and yolk were distinct, each in its proper membrane; the white showed an alkaline reaction; the yolk neither an acid nor alkaline; mixed with hydrate of lime, neither afforded a perceptible smell of ammonia.

A second trial with unimpregnated eggs, conducted in the same manner as the preceding, was made with some from a Bantam hen that had been kept secluded. Five of her eggs a few days old (the oldest ten days) were put under a hen on the 21st November, with two ordinary eggs, which in due time were hatched, producing healthy chickens. On examination, after twenty-one days, two of the Bantam eggs were found broken. The remaining three were undergoing putrefaction; their contents were very offensive, a fluid, of a greenish hue, containing scattered through it small masses of a dark green colour, almost black. Under the microscope, its lighter portion exhibited granules and oil globules, its darker

matter that of a hyaloid transparent substance without cells. The fluid was coagulated by heat. The air collected from one of them consisted of 40 per cent. carbonic acid, 2 oxygen, 58 azote.

No contrast could be greater than the appearance and state of the unimpregnated eggs in these two trials; in the first, with the exception of No. 3, so little changed, in the last so much changed, so much so as to be suggestive of the death of the eggs, the formation of mucedo, and of its death and decomposition, the colouring matter remaining.

II. *Of Eggs kept at a Temperature of about 32° Fahr.*

On the 24th of June, four newly laid eggs were put into an ice-house, where they were left until the 19th of July. Cracks were found in two of them when taken out, but without any exudation of contents. These cracks might denote the freezing of the eggs. Put under a hen on the evening of the 17th, with nine fresh eggs, the latter were hatched on the 10th of August, as was also one of the former; the two cracked eggs were crushed. The fourth from the ice-house, when broken was found to contain a mixture of yolk and white in the form of emulsion, with some unmixed yolk in a thickened state. The contents had an unpleasant smell, as if from incipient putrefaction.

III. *Of Eggs subjected to the Air-Pump.*

1. On the 14th of April six newly laid eggs were thus treated until the 23d. The air-pump was in good order, and it was worked twice or thrice daily. On the 23d, these eggs were put under a hen with seven newly laid ones. The hatching began on the 13th of May; on the 14th all were hatched with the exception of one,—one of those subjected to the air-pump: this egg swam in water; had, when broken, an unpleasant smell, denoting incipient putrefaction; and the white and part of the yolk were mixed, forming a yellow opaque emulsion. There was an obscure appearance of an embryo in that portion of the yolk which was retained in its membrane. The newly laid eggs were hatched a few hours earlier than those acted on by the air-pump.

2. Three newly laid eggs, on the 28th of May, weighed as follows:—

No. 1 weighed 874·8 grs.	No. 3 weighed 953·0 grs.
2 ... 912·0 „	

They were subjected to the air-pump until the 2d of June, when, on weighing, they were found to have sustained the following loss:—

No. 1, ... 4·8 grs.	No. 3, ... 5·1 grs.
2, ... 4·0 „	

They were put into water, and again subjected to the air-pump, which was worked

twice or thrice daily. Taken out on the 18th of June, they were found to have gained as follows:—

No. 1, ... 8.2 grs.	No. 3, ... 11·3 grs.
2, ... 8·3 „	

They were now put under a hen, with seven newly laid eggs. On the 9th of June all the seven were hatched, but neither of the three.

No. 1, when weighed, was found to have lost 30·8 grs. It sank in water. No traces could be detected in it of an embryo. It contained a bright yellow emulsion, a mixture of yolk and white, free from any unpleasant smell, of specific gravity 1036; it was neutral to test papers. The chalazæ and membranes were shrunk together.

No. 2 had sustained a loss of 81 grs. Air procured from it was found to consist of about 18 per cent. carbonic acid, 82 azote. Its contents were very offensive and putrid, liquid and greenish, with a dark green clotted sediment. This under the microscope exhibited corpuscles, varying in diameter from 1500 of an inch to 1000; they were nearly circular, and contained greenish nucleoli.

No. 3 had sustained a loss equal to 81·6 grs. It contained a yellowish emulsion of specific gravity 1035. Some of its white still remained in its membrane in a thickened state. The fluid part had a putrid smell, but less offensive than the preceding.

3. On the 23d of June four newly laid eggs weighed as follows:—

No. 1 weighed 966·1 grs.	No. 3 weighed 886·8 grs.
2 ... 786·4 „	4 ... 830·4 „

They were put into water the same day—water deprived of air by the air-pump—and were subjected to the action of the pump. No air came from the water, but a good deal from the eggs. The pump was worked daily. On the 25th of June a little air still continued to be given off from the eggs. On the 27th there was a cessation; nor until the 19th of July did any more appear; then two or three bubbles were seen to rise from one of the eggs. Now taken out and weighed, they were found to have gained as follows:—

No. 1, ... 7·3 grs.	No. 3, ... 7·6 grs.
2, ... 7·0 „	4, ... 8·2 „

No. 1 was broken for examination. Its white appeared rather more liquid than common. Its specific gravity was 1033. The cicatricula seemed somewhat enlarged. The yolk was not apparently altered. There was no unpleasant smell either from the white or the yolk. On the exterior of its shell, and of the shell of the other three, there were minute opaque white spots, with a central aperture, distinguishable by the naked eye; the spots were a little depressed. The appearance was suggestive of solution by a current of air (carbonic acid?) from

the egg under the action of the air-pump. They were mostly in the big end, but they were not confined to that end.

The remaining three eggs were put under a hen with ten recently laid. The latter were hatched on the 11th of August. Of the eggs subjected to the air-pump, No. 4 only was hatched, and only about four or six hours later than the ten. The chick was healthy. The two aborted eggs were found to have lost as follows:—

No. 2, ... 53·9 grs.	No. 3, ... 32·16 grs.

Both sank in water. Of No. 2 the yolk and white were in part mixed; a portion of the white was free and thickened. The contents had no unpleasant smell; no embryo could be found. Of No. 3 the yolk and white were found distinct, each in its proper membrane. In neither of them was there any apparent change, except that the white seemed more liquid than usual. Neither had any offensive smell, merely that of a stale egg.

IV. *Of Eggs kept in Lime Water.*

1. On the 17th of July three newly laid eggs were put into lime water, in which there was a great excess of lime. They weighed as follows:—

No. 1 weighed 1024·5 grs.	No. 3 weighed 937·1 grs.
2 ... 900·5 „	

The vessel used, which was of glass, held little more than a pint; it was full nearly to the mouth, and the mouth was only just large enough to admit the eggs. It was closed by a cork, and placed in a dark cupboard, where the temperature was about 63°, and subject to little variation. Taken out on the 17th of September (the water was covered with a crust of carbonate of lime), they were found to have gained as follows:—

No. 1, ... 2·3 grs.	No. 3, ... 4·0 grs.
2, ... ·6 „	

On the same day they were put under a hen with seven fresh eggs. Of the latter all but one were hatched on the 11th of October. This one, on receiving a blow, broke explosively, scattering wide its yellow, offensive contents; the explosion was nearly as loud as that of a pistol, showing how much the air it contained was compressed. Each of the eggs from lime water was unproductive. They were found to have lost as follows:—

No. 1, ... 25·7 grs.	No. 3, ... 10·9 grs.
2, ... 11·1 „	

All three sank in water. No. 1, broken under water, gave off two or three bubbles of air; the quantity was too small for analysis. The yolk and white were distinct, but the former seemed unduly thin, as if from the admixture of

some of the white. Both showed an alkaline reaction, but the white the strongest. The contents of No. 2 were similar. No. 3 was not examined.

2. On the 26th of March thirteen eggs, which, when newly laid, had been placed in lime water,—some in the last week of February, some a few days later, but with less precaution than in the preceding trial,—were put under a hen. Of these one only was hatched, and on the 17th of April. The chick was healthy; the rest all aborted. In five of them embryos were found more or less advanced; in the other four no traces of an embryo could be detected; their contents varied much in quality. Of one the yolk and white were distinct, each in its membrane, and so little altered, that the yolk retained its natural acid reaction, as well as the white its alkaline. The contents of the others were free from any marked putridity.

V. *Of Eggs in the Ordinary Process of Incubation.*

For the sake of comparison, I shall now notice briefly the results obtained in ordinary instances of incubation with eggs presumed to be impregnated, and which had in no way been interfered with.

1. On the 27th of June thirteen eggs were put under a hen. Of these six were newly laid; of the other seven, reckoning from the time of laying,

No. 1 had been kept		36 days.	No. 5 had been kept		31 days.
2	...	35 „	6	...	29 „
3	...	34 „	7	...	25 „
4	...	33 „			

Of the six newly laid, three were hatched, three aborted. All three just swam in water; one, opened under water, afforded a little air, which was found to consist of 20·6 oxygen, 79·4 azote. Each of them contained a well-advanced fœtus.

Of the seven, the numbers of which have been given according to the time of keeping or age, all but the first three were hatched, giving birth to healthy chickens. Of the unproductive three neither contained an embryo, or showed any signs of development.

No. 1 contained a pale, thick, yellowish matter; it had a smell like that of sour milk; had an acid reaction; was of the consistence of soft curd, and had much the same appearance.

Of No. 2 the contents were liquid, with little viscidity; of a richer yellow than the preceding; had an alkaline reaction, and was of the specific gravity 1032. Distinct from the yellow liquid there was a small portion of glairy white. The contents of No. 3 showed no well-marked difference.

The hatching in this instance was unusually prolonged; the first chick appeared in the night of the 16th, the last of the seven in the night of the 18th. After that the hen deserted her nest, and may have been the occasion of the death of the advanced fœtuses; neither of them showed any signs of putridity.

2. Of sixteen duck's eggs put under two hens in May, all but four were hatched. Of these four, two were found to contain each a fœtus well advanced. In the other two there were no traces of development. Of one of these the white and yolk were distinct, and little altered; of the other the white and yolk were commingled, very liquid, and had a slight disagreeable smell. It is worthy of remark, that there was a thick layer of mucor (*M. mucedo*) on the air vesicle of each of the eggs containing a fœtus; it was nearly black; in a less degree it was found on the lining membrane of the shell of all three. Air from one of these eggs, equal in volume to ·67 cubic inch, consisted of about 20 oxygen and 80 of azote.

3. Ten eggs were put under a hen on the 24th of February. Three only were hatched. The seven unproductive eggs swam in water. In the first examined a fœtus was found well advanced; the fluid brownish and offensive. In the second the yolk and white were mixed, of a yellow colour, curdly, and offensive. In the third the contents were similar, but only slightly offensive. In the fourth they were more liquid, not curdly, very slightly offensive. In the fifth the yolk and white were only partially mixed, of a bright yellow, and not offensive. In the sixth there was a fœtus about one quarter the size of that of the first; the yolk and white mixed, of a dirty yellow, and offensive. In the seventh there was also a fœtus; it was less advanced than that of the first, but more than that of the last; the yolk was brownish-yellow, the white gelatinous and transparent; both offensive.

VI. *Conclusions.*

What are the conclusions to be drawn from the foregoing results? The changes experienced in the egg, as described in the several experiments, are so many and various, and the difficulty of referring them to their causes is so great, that I have much hesitation in drawing any decided inferences from them, especially as regards suspension of vital action, in the trials, whether with the air-pump, lime-water, or ice-house, in which incubation was afterwards successful.

In the various experiments, it may be said that the whole of the oxygen was not withdrawn from the eggs, that a minute portion remained sufficient to maintain a very low degree of vitality, enough, at least, to place in equilibrium for a time the antagonistic agencies—those administering to life and death. I shall relate one experiment which seems favourable to this view. On the 13th of May three newly laid eggs were put into water sufficient to cover them, and, with a piece of phosphorus placed by the side of the containing vessel, were subjected to the air-pump until the 28th. After the greater portion of the air had been extracted from the water and the eggs, the phosphorus ceased to shine until the instant that the pump was worked (it was worked twice or thrice daily, and was in good order); then there proceeded from it flashes of light, lighting up the interior of the bell-glass, suggestive of its vapour being diffused through the

aqueous vapour filling the receiver, and of the disengagement of a little air from the eggs, the cause of the combustion or luminous appearance. Not until the last night was there a cessation of the phenomenon. On the following day, the 28th, the eggs, with a certain number of fresh eggs, were put under a hen; owing to an accident, the hatching process was interrupted. After an incubation extended to the 20th of June, one of the three eggs was found to contain a fœtus; the other two, in an unknown manner, had been taken from the nest. That in this instance a very minute portion of oxygen might have remained in the egg —a portion not exhausted by the air-pump—seems not improbable. Thus much granted, there seems little difficulty in admitting the persistence of a feeble action in the egg in question, and this a vital action, similar to that which, it may be inferred, is in progress in the ordinary egg when in a fit state for hatching—a condition limited as to time, and in the common fowl seldom exceeding thirty days.

If considerations of this kind render the results obtained from the vacuum eggs inferentially questionable, they are not less applicable to the results of the trials of the eggs kept in lime water and the ice-house. Under lime water access of air only is excluded. The little air in the egg may suffice for sustaining a very feeble action, sufficient for the preservation of life for a limited time. In an ice-house, at a temperature of 32°, or lower, if not low enough to freeze the egg, action may be diminished seemingly, but not be really arrested. The ova of the salmon, it has recently been ascertained, are capable of being hatched after having been kept in ice-water one hundred and twenty days, and thus conveyed to Australia. Whether there can be life without action, or its equivalent change, is a problem which I hardly venture to approach. In the seeds of certain vegetables, which, circumstances not favouring, remain without germinating months and years, there seems to be during the period an arrest of vital force or action; and yet, may it not be more apparent than real? When we reflect that each kind of seed, like each kind of egg, has its term of retension of vitality—the longest, in the instance of the seed, little exceeding thirty years—we may be allowed to have our doubts on the subject. It is possible that during the whole period, however long, there may be a very feeble action, though imperceptible, sustaining life. It may be well to reflect on the coarseness of our measures of time, and that great cosmic changes, which require hundreds and thousands of years to become conspicuous, are produced by causes in continued operation, which are absolutely inappreciable in their momentary effects. An instance of this is afforded by the worn-foot of the bronze statue in St Peter's, so worn by the kisses of devotees during hundreds of years. What we witness in certain hibernating animals seems to favour our doubts. In the instance of the dormouse, in the depth of winter, there are no distinct indications observable of life; its temperature is about that of the air; no arterial action is perceptible; yet it would appear that the heart's action, and the action of the secreting organs, is not

absolutely suspended. Even congelation itself, it may be conjectured, may be compatible with the retention of a low vital force, more or less morbid or deranged; at least, congelation, I have found, does not entirely arrest action in the blood, ammonia being formed in it, and evolved from it when frozen.*

Relative to the varied changes witnessed in the aborted or unproductive eggs —some amounting to putrefactive decomposition, some indicative of the formation of new compounds, some so inconsiderable as to be only just appreciable—it is difficult to offer any satisfactory explanation, especially as, in every instance of incubation, all have been apparently very similarly acted on. Mr HUNTER has expressed the opinion that eggs which have "not hatched become putrid in nearly the same time with any other dead animal matter.† This statement is not supported by the preceding results. At one time I was disposed to infer, from various experiments I had made, some of which are to be found in the last volume of my "Physiological Researches," that the circumstance which most favours the putrefactive change in the egg is the commingling of the white and yolk. But from later experiments, especially one recently made, my confidence in this opinion has been shaken. The experiment was the following:—Eight newly laid eggs were wrapped in paper, placed in a basket, and covered with paper, in a room, the temperature of which ranged from about 50° at night to 55° by day. The placing them was begun on the 27th of November, and continued as follows, each egg being weighed at the time:—

No. 1, November	27,	weighed	831·3 grs.	No. 5, December	5,	weighed	890·5 grs.
2, ...	28,	...	991·0 „	6, ...	8,	...	862·4 „
3, ...	30,	...	842·5 „	7, ...	10,	...	869·0 „
4, December	2,	...	893·4 „	8, ...	13,	...	1012·5 „

They were left undisturbed until the 30th of January, when they were taken out and again weighed.

No. 1 was found to have lost	2·4	per cent.	
2	3·2	„	
3	3·5	„	
4	3·3	„	
No. 5 was found to have lost	2·9	per cent.	
6	3·0	„	
7	3·0	„	
8	2·2	„	

These eggs were now put under a hen with five fresh ones. On the 28th of February the latter were all hatched; the former were found to have failed.

No. 1 had sustained a further loss of	15·8	per cent.	
2	14·4	„	
3	13·8	„	
4	16·6	„	
No. 5 had sustained a further loss of	14·7	per cent.	
6	12·2	„	
7	12·1	„	
8	5·8	„	

This trial was made on the idea that, by checking evaporation, and by perfect

* See Transactions Roy. Soc. of Edin. vol. xxiv. p. 26.
† Philosph. Trans. for 1778, p. 29.

rest, a retardation might be effected of the changes unfavourable to life, and that it might be indicated by some traces of vital development in the eggs. But the results were all of the contrary kind; in no one of the eggs were there any marks of development. Two of them, No. 4 and No. 8—the one which had sustained the greatest loss during incubation, the other which had sustained the least—were opened under water. The air from No. 4, a little more than half a cubic inch, was found to consist of 1 per cent. carbonic acid, 19 oxygen, 80 azote; whilst that of No. 8, somewhat less in quantity, consisted of 2·5 carbonic acid, 5 oxygen, and 92·5 azote. The contents of the two differed considerably. Those of No. 4 were a mixture of yolk and white, forming a yellow fluid, of little viscidity, of no unpleasant smell, of faint alkaline reaction, and giving off with quicklime a slight smell of ammonia. The contents of No. 8 had an offensive smell, approaching the putrid, a duller colour, a more distinct alkaline reaction, and mixed with lime, a stronger ammoniacal odour. The contents of the other eggs, with the exception of No. 7, were found to resemble very much No. 4. They had no unpleasant smell, and, if anything, they were of a brighter yellow, and of feebler alkaline reaction. No. 7 had undergone a greater change; its contents were of a greenish-mottled hue, nowise viscid, of unequal consistence, partially curdled, of a very offensive putrid smell, strong alkaline reaction, and with lime emitting a strong smell of ammonia. Under the microscope it was seen to consist of very fine granules and of globules or cells, like those of a mucedo, in which, it may be inferred, that the colouring matter existed. Now, as in all these eggs, excepting one, putridity had not taken place, though the yolk and white had become intimately mixed, and were exposed to a temperature favourable to the change, it seems pretty evident that a mere admixture of the two is not adequate to excite the putrid fermentation, and that something else is essential. But what that something is, I cannot at present venture to conjecture. It seems to me that the putrefaction of the egg, as regards its *vera causa*, is as yet nearly as much unsolved as that of the coagulation of the blood, and, like it, may perhaps be considered as belonging to the great mystery of life and death.

XXVII.—*Report on the Hourly Meteorological Register kept at Leith Fort in the Years* 1826 *and* 1827. By Sir David Brewster, K.H., D.C.L., F.R.S. (Plates XXIV. and XXV.)

(Read 19th February 1866.)

Having already published in the Transactions* a detailed report on the Hourly Meteorological Register kept at Leith Fort, at the expense of the Society, during the years 1824 and 1825, it is unnecessary to enter into any recapitulation respecting the origin and history of this class of observations.

The singular and unexpected results obtained from these Registers, and the rapid approximation to general laws which some of these results exhibited, attached a great interest to the observations of future years; and it is satisfactory to find that the results for the two following years of 1826 and 1827 are almost perfectly coincident with those for 1824 and 1825, not only in their general relations, but even in their numerical laws.

The following are the Mean Temperatures of the four years during which the hourly observations were made at Leith Fort:—

Mean Temperature of 1824,	47°·588
„ „ of 1825,	48·911
„ „ of 1826,	48·436
„ „ of 1827,	48·407
Average Mean Temperature of four years,	48·335

The following Tables contain the mean temperatures for every day of the year, and for every hour of the day for 1826 and 1827:—

* Vol. X. p. 362.

MEAN RESULTS OF THE HOURLY REGISTER FOR 1826.

The Mean Temperature of the Winter Months, viz. Dec. Jan. Feb. is . . . 40°·556
" " of the Spring Months, viz. March, April, May, . . . 46·135
" " of the Summer Months, viz. June, July, August, . . 58·263
" " of the Autumn Months, viz. Sept. Oct. Nov. . . . 48·818

The Mean Temperature of the Year 1826, from 8760 observations, is . . . 48·436

TABLE I.—Containing the Daily and Monthly Mean Temperatures for 1826.

Day.	January.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	32·94	40·40	45·49	46·48	44·65	54·09	62·04	56·77	56·46	56·44	43·54	39·29
2	37·77	43·82	41·40	46·55	49·03	49·88	61·66	52·96	58·57	52·69	43·21	40·38
3	39·42	47·92	42·28	51·29	42·57	51·33	61·96	56·50	58·35	51·78	41·67	36·38
4	37·34	43·26	42·38	49·65	43·09	52·84	60·47	56·58	57·90	47·55	43·62	35·00
5	36·54	43·21	39·15	50·21	45·75	52·69	60·94	56·20	53·25	45·06	46·41	31·51
6	36·21	47·54	41·59	50·40	43·00	58·88	62·50	56·00	53·58	47·73	39·08	32·75
7	36·16	42·77	43·22	49·33	45·55	53·97	60·58	59·97	56·82	55·53	39·08	41·99
8	30·69	46·84	44·08	53·87	44·38	54·92	62·26	58·42	54·04	48·02	39·09	44·09
9	24·36	47·34	54·57	50·27	44·26	49·00	56·31	54·86	52·68	45·96	38·37	44·31
10	30·98	48·55	59·20	46·01	48·40	50·80	57·47	54·25	54·20	48·24	44·22	46·92
11	31·26	39·08	50·57	48·17	47·49	54·33	57·77	55·86	55·15	51·27	50·29	50·01
12	29·45	43·75	43·92	47·50	48·16	60·35	55·46	56·15	56·50	51·16	41·80	48·91
13	25·49	45·60	41·26	46·31	51·72	62·35	56·47	60·40	59·02	50·41	39·11	46·76
14	20·94	43·31	39·65	49·72	53·86	57·45	52·38	62·17	54·36	49·15	37·71	44·25
15	22·03	46·26	41·18	46·97	54·38	54·88	53·85	61·96	50·82	56·05	38·72	45·15
16	24·01	46·79	39·06	46·10	49·90	51·51	55·36	60·51	56·55	54·85	35·42	44·42
17	40·79	42·04	38·88	46·99	54·78	55·14	54·42	61·58	60·25	52·37	39·15	44·05
18	43·75	37·00	43·48	47·65	57·67	56·99	56·60	69·75	53·07	48·26	37·65	43·16
19	34·94	38·75	42·36	50·67	52·54	55·34	54·34	68·23	55·01	48·55	41·09	38·86
20	40·15	39·17	44·24	53·73	49·32	57·47	51·44	62·44	54·09	52·76	39·00	39·99
21	43·30	41·55	43·22	49·80	52·27	54·63	50·42	59·72	51·99	54·71	39·70	37·46
22	39·21	48·06	39·65	49·27	53·71	52·27	50·14	57·94	52·16	54·21	42·97	45·29
23	40·32	39·65	39·44	44·45	48·90	56·52	50·16	63·74	51·21	56·11	45·38	47·66
24	37·76	43·15	39·22	43·16	49·75	65·11	53·94	63·53	52·87	56·05	38·94	47·60
25	40·95	43·67	36·92	41·17	51·31	68·79	57·60	63·28	53·90	50·91	35·87	44·96
26	38·15	41·78	36·71	42·11	46·32	69·34	58·01	60·04	60·08	45·09	34·52	40·12
27	38·37	41·35	40·60	35·91	50·28	64·11	61·80	60·26	59·05	48·12	31·48	39·17
28	40·09	47·78	44·91	35·30	51·47	67·01	64·20	59·87	55·00	47·86	38·99	42·65
29	41·16	...	37·22	37·85	50·48	64·31	62·09	64·15	58·57	47·55	42·72	45·12
30	43·72	...	38·26	41·44	50·79	64·66	62·46	61·94	61·31	45·87	43·88	47·67
31	44·42	...	41·46	...	51·13	...	61·69	57·67	...	44·26	...	47·58
Mean Temp. of each Month.	35·570	43·407	42·438	46·611	49·269	57·365	57·633	59·792	55·561	50·470	40·423	42·692

The Mean Temperature of 1826 is, by this Table, 48°·436.

TABLE II.—Showing the Mean Temperature of each Hour for each Month in 1826, and for the whole Year.

Hour.	January.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Temp. of each Hour for the whole Year.
1 A.M.	33·822	41·723	40·492	43·650	45·234	52·833	53·274	56·790	53·125	48·363	39·242	42·193	45·916
2 ...	33·927	41·812	40·089	42·975	44·645	51·975	52·927	56·274	52·767	47·976	39·100	42·089	45·565
3 ...	33·926	41·562	39·960	42·700	43·822	51·367	52·871	55·645	52·267	47·863	39·125	42·145	45·289
4 ...	33·880	41·822	39·855	42·433	43·710	51·225	53·008	55·427	52·242	47·960	39·142	41·976	45·240
5 ...	33·890	41·750	39·331	42·358	44·153	51·700	52·742	54·863	51·808	48·057	39·283	41·742	45·154
6 ...	33·890	41·732	39·355	42·925	44·968	52·725	53·863	55·847	51·833	47·960	39·383	41·605	45·525
7 ...	33·863	42·009	39·516	43·958	46·145	53·917	55·250	57·307	52·750	48·000	38·992	41·653	46·133
8 ...	34·169	42·281	40·468	45·358	47·661	55·358	56·685	58·307	53·750	49·129	39·550	41·935	47·075
9 ...	35·024	43·527	41·806	47·075	49·572	57·075	58·161	59·363	55·325	50·807	40·008	42·145	48·347
10 ...	35·952	44·277	43·331	48·125	50·322	58·400	59·282	60·597	56·917	52·379	40·685	42·693	49·438
11 ...	36·661	44·795	44·258	48·958	51·500	60·150	60·073	61·766	58·400	51·984	41·640	43·395	50·407
12 ...	37·557	44·973	45·290	49·985	52·274	61·150	60·806	63·057	59·167	53·863	42·433	43·670	51·214
1 P.M.	38·210	46·134	45·758	50·400	53·065	62·192	61·427	63·347	58·973	54·153	42·790	43·943	51·724
2 ...	38·274	46·295	46·169	49·917	53·581	62·425	62·185	63·726	59·333	54·162	42·907	44·161	51·958
3 ...	38·200	46·170	46·081	50·208	53·613	62·650	62·282	63·920	59·300	54·065	42·617	43·853	51·941
4 ...	37·677	45·402	45·645	50·650	53·992	63·092	62·540	64·468	59·557	53·516	42·017	43·605	51·879
5 ...	36·758	44·661	45·476	50·692	53·903	63·367	62·653	64·137	59·092	52·411	41·433	43·415	51·533
6 ...	36·202	43·920	43·935	50·475	53·879	62·858	62·428	63·912	57·807	51·121	40·717	43·307	50·915
7 ...	35·798	43·553	43·072	48·433	52·306	61·417	61·000	62·645	56·358	50·540	40·342	43·057	49·910
8 ...	35·476	43·286	42·516	47·108	50·693	59·025	58·057	60·813	55·683	50·307	40·067	42·847	48·851
9 ...	35·363	42·857	41·984	46·283	49·548	56·975	56·589	59·476	54·792	49·508	39·873	42·532	48·008
10 ...	35·226	42·678	41·540	45·675	48·540	55·908	55·726	58·670	54·323	49·097	40·000	42·379	47·504
11 ...	34·903	42·420	40·911	44·800	47·701	55·183	55·387	58·210	54·067	48·677	39·773	42·137	47·036
12 ...	34·702	42·312	41·000	44·017	47·298	54·033	54·492	57·670	53·633	48·484	39·692	42·121	46·670

The Mean Temperature obtained from the last column in the above Table is 48°·468.
It occurred at $9^h\ 7^m$ A.M. and $8^h\ 27^m$ P.M.

HOURLY REGISTER FOR 1827.

The Mean Temperature of the Winter Months, viz. Dec. Jan. Feb. is . . . . 38·945
" " of the Spring Months, viz. March, April, May, ... 45·817
" " of the Summer Months, viz. June, July, August, ... 57·612
" " of the Autumn Months, viz. Sept. Oct. Nov. . . . . 51·255

The Mean Temperature of the Year 1827, is . . . . . 48·407

TABLE III.—Containing the Daily and Monthly Mean Temperatures for 1827.

Day.	January.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	43·68	37·64	41·70	48·79	47·61	54·50	56·92	61·67	56·09	56·48	41·71	45·29
2	28·22	35·60	34·63	50·99	51·25	52·36	55·58	62·69	59·35	54·43	48·31	43·25
3	20·44	33·29	33·34	50·36	53·23	49 80	57·59	61·83	57·73	55·75	49·38	46·67
4	28·26	36 27	32·86	48·53	54·84	52·34	59·47	56·80	55·79	54·71	48·30	53·14
5	27·85	41·22	33·77	51·13	52·11	50·71	59·99	59·05	56·69	52·57	48·62	50·49
6	44·88	40·05	38·50	48·34	46·39	51·91	61·62	55·41	55·51	56·58	43·60	40·73
7	48·97	37·90	32·76	46·85	44·83	53·15	59·41	58·82	56·72	54·06	43·00	45·38
8	48·95	35·98	30·34	47·87	47·14	57·37	62·71	59·31	56·50	52·51	44·27	42·48
9	38·66	35·45	32·96	49·05	47·95	61·23	59·37	61·67	58·69	54·08	50·18	43·95
10	38·75	38·72	36·46	46·12	43·42	61·23	57·75	57·43	62·89	48·11	49·26	49·56
11	32·31	37·93	41·84	44·39	45·95	61·34	56·58	55·92	63·56	50·65	43·89	46·69
12	29·38	36·26	41·99	47·58	50·93	60·87	57·17	55·14	57·01	50·52	49·25	40·91
13	40·48	35·13	40·67	47·31	54·18	57·56	57·61	56·95	55·75	48·35	55·23	40·75
14	40·97	36·13	39·58	48·53	49·19	57·63	57·09	53·76	58·62	48·37	53·33	44·96
15	35·25	32·41	37·10	47·81	48·72	56·12	60·30	52·54	62·62	56·58	43·13	45·12
16	28·92	30·36	40·27	45·74	48·58	61·45	65·01	51·35	63·91	58·01	46·29	41·85
17	35·46	31·24	42·78	44·53	51·66	57·98	65·37	53·86	62·68	55·53	44·10	45·43
18	37·21	28·35	38·72	42·08	48·53	56·66	59·78	53·38	55·61	51·98	36·44	43·19
19	37·44	28·69	47·42	42·93	54·46	54·33	56·59	55·12	49·98	53·98	38·44	46·59
20	35·32	31·58	47·15	43·01	53·37	50·88	55·46	54·42	56·53	54·04	44·42	41·98
21	35·96	35·09	47·65	42·38	59·12	52·59	56·10	57·86	56·66	53·24	33·48	43·08
22	35·37	33·30	50·71	40·69	56·89	53·23	58·33	55·87	57·46	50·05	31·58	41·34
23	33·13	35·92	51·91	35·54	54·75	53·77	59·58	58·55	57·50	50·15	33·08	40·41
24	34·01	36·21	46·14	34·65	56·76	54·95	64·58	57·57	56·22	53·26	32·35	46·47
25	36·11	35·85	38·69	37·53	50·46	57·63	61·54	55·58	57·56	54·02	38·83	45·97
26	35·77	46·05	40·17	41·39	51·03	58·16	56·64	54.87	56·50	55·12	42·71	50·88
27	30·96	40·41	45·12	45·75	51·21	58·60	59·73	59·81	55·42	52·51	47·98	45·66
28	45·73	37·36	40·61	47·49	54·66	58·53	62·72	56·96	54·95	43·96	49·98	40·72
29	48·19	...	38·12	50·25	56·35	58·02	63·53	56·21	55·86	43·46	48·45	32·67
30	45·26	...	40·55	51·25	57·02	57·98	62·67	59·61	55·61	46·69	47·33	30·62
31	43·52	...	42·15	...	57·26	...	63·97	58·15	...	42·65	...	42·69
Mean Temp. of each Month.	37·271	35·728	40·215	45·628	51·608	56·096	59·702	57·037	57·532	52·013	44·221	43·836

TABLE IV.—Showing the Average Mean Temperature of each Hour for each Month in 1827, and for the whole Year.

Hour.	January.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Mean Temp. of each Hour for the whole Year.
1 A.M	37·121	34·982	38·508	43·275	48·718	52·091	56·056	54·379	56·050	52·597	43·550	43·282	46·717
2 ...	37·097	34·955	38·395	42·925	48·161	51·491	55·492	53·685	55·608	52·589	43·368	43·129	46·408
3 ...	36·935	35·080	38·290	42·500	47·750	51·016	54·863	52·935	55·433	52·403	43·116	43·185	46·125
4 ...	36·734	35·160	38·169	42·356	47·790	51·258	54·677	52·693	55·241	52·153	43·000	43·290	46·043
5 ...	36·508	34·768	37·855	42·508	48·072	51·850	55·201	52·976	55·550	51·903	42·808	43·282	46·107
6 ...	36·532	34·553	38·185	43·083	48·645	52·866	56·145	53·306	55·800	51·763	42·733	43·322	46·411
7 ...	36·419	34·643	38·516	43·291	49·492	54·066	57·605	54·911	56·091	51·677	42·841	43 242	46·899
8 ...	36·701	34·652	39·185	44·475	50·234	55·716	58·725	56·330	56·850	51·556	43·008	43·411	47·570
9 ...	36·911	35·134	40·379	45·608	51·218	57·075	60·105	57·355	57·516	51·580	43·491	43·548	48·327
10 ...	37·250	35·768	41·201	46·800	51·895	58·121	61·306	58·182	58·075	52·057	44·183	44·008	49·070
11 ...	37·605	36·518	42·387	48·041	53·145	58·783	62·153	59·435	58·650	52·476	45·375	44·556	49·927
12 ...	38·072	37·375	42·750	48·658	53·492	59·400	62·951	60·290	59·233	52·355	46·400	45·153	50·511
1 P.M.	38·129	37·259	43·395	49·016	54·185	59·975	63·589	60·871	59·641	52·193	46·908	45·201	50·863
2 ...	38·362	37·625	43·371	49·066	54·734	60·541	63·516	61·161	59·607	52·258	46·991	45·209	51·037
3 ...	38·282	37·419	42·927	49·183	54·879	60·725	63·806	60·814	59·966	51·968	46·600	44·943	50 959
4 ...	38·064	37·089	42·645	48·950	54·943	60·633	64·056	60·669	60·233	51·888	45·800	44·339	50·776
5 ...	37·911	36·616	41·935	48·300	54·943	60·400	63·363	60·323	60·283	51·637	45·458	44·242	50·451
6 ...	37·564	36·202	40·935	47·566	54·137	59·750	62·951	59·863	59·075	51·532	44·866	43 830	49·856
7 ...	37·218	35·785	39·958	46·541	53·709	58·191	62·387	58·967	58·558	51·516	44·616	43·766	49·268
8 ...	37·153	35·563	39·896	45·658	52·355	56·841	61·185	57·669	58·000	51·847	44·275	43·637	48·673
9 ...	36·968	35·330	39·605	45·041	51·750	55·341	59·571	56·750	57·300	52·161	44·075	43·540	48·119
10 ...	36·927	35·259	39·193	44·391	51·097	53·625	58·274	56·048	56·841	51·944	44·008	43·242	47·571
11 ...	37·008	35·321	38·887	44·050	50·314	53·541	57·532	55·427	56·891	52·201	43·900	43·484	47·379
12 ...	36·959	35·357	39·024	43·691	49·629	52·733	57·209	54·597	56·300	52·330	43·850	43·589	47·105

The Mean Temperature obtained from the last column in the above Table is 48°·423.

The Mean Temperature of 48°·423 occurs at $9^h\ 12^m$ A.M. and $8^h\ 23^m$ P.M.

The general results which may be deduced from the preceding Tables relate—

1. To the form and character of the annual and monthly daily curves, or the daily progression of temperature.

2. To the arrangement of the monthly curves in separate groups.

3. To the determination of the times of the day when the mean temperature occurs.

4. To the relation between the mean temperature of the day, and that of any single hour or pair of similar or *homonymous* hours.

5. To the parabolic form of the four branches of the annual daily curve.

I. *On the Form and Character of the Annual and Monthly Daily Curves, or the Daily Progression of Temperature.*

The mean temperature of the year 1826 was 48°·436, and that of 1827 48°·407, both of them intermediate between that of the two preceding years; but though in its average character the temperature of 1826 was moderate, yet it differed from both of them in a remarkable manner. Though the mean annual curves of 1824 and 1825 differ from one another, from the former representing a *cold* and the latter a *warm* year, yet they are perfectly parallel, indicating the same vicissitudes of climate. The curve of 1826, however, exhibits the character of an American climate, descending almost as low as that of 1824 in the morning branch, and rising nearly as high as 1825 in the warm period of the day.

The curve for 1827 differs remarkably from that of 1826, keeping above it from 1 o'clock in the morning till 8 o'clock in the evening, but almost touching it at the morning and evening hours of mean temperature. See Plates XXIV. and XXV.

In all the curves for these four years, the lowest temperature took place at 5 o'clock in the morning. The temperature increased, with great regularity, till 3 o'clock in the afternoon, when it descended to its minimum. The period, therefore, of its ascending is *ten* hours, and that of its descending motion *fourteen* hours.

By comparing the summer and winter curves or the mean temperatures of the six summer months, from April to September inclusive, with those of the six winter months, from October to March inclusive, as exhibited in the annexed Table, we are enabled to discover whether or not the peculiar character of 1826 is derived from the warm or the cold season.

TABLE, SHOWING THE MEAN TEMPERATURE OF EACH HOUR FOR THE SIX SUMMER MONTHS, FROM APRIL TO SEPTEMBER INCLUSIVE, AND FOR THE SIX WINTER MONTHS, FROM OCTOBER TO MARCH INCLUSIVE, FOR 1826 AND 1827.

	1826.			1827.	
Hours.	Six Summer Months.	Six Winter Months.	Hours.	Six Summer Months.	Six Winter Months.
	°	°		°	°
1 A.M.	50·818	40·972	1 A.M.	51·761	41·667
2	50·260	40·832	2	51·227	41·589
3	50·112	40·763	3	50·749	41·501
4	49·667	40·772	4	50·669	41·418
5	49·604	40·675	5	51·026	41·187
6	50·366	40·654	6	51·641	41·181
7	51·554	40·672	7	52·576	41·223
8	52·853	41·255	8	53·721	41·419
9	54·428	42·219	9	54·813	41·900
10	55·604	43·219	10	55·396	42·411
11	56·808	45·123	11	56·701	43·153
12	57·740	44·590	12	57·337	43·684
1 P.M.	58·234	45·165	1 P.M.	57·846	43·848
2	58·528	45·271	2	58·104	43·969
3	58·662	45·104	3	58·229	43·689
4	56·731	44·647	4	58·247	43·304
5	59·333	44·026	5	57·935	42·966
6	58·726	43·200	6	57·224	42·488
7	57·026	42·727	7	56·292	42·143
8	55·229	42·416	8	55·285	42·062
9	53·943	42·019	9	54·292	41·946
10	53·141	41·820	10	53·379	41·766
11	52·561	41·470	11	52·959	41·800
12	51·857	41·385	12	52·359	41·851
Mean,	54·324	42·541	Mean,	54·574	42·257

The summer curve of 1826 retains the same intermediate position between those of 1824 and 1825 that it did in the annual curve; but in the morning hours it descends nearly to the curve of the cold year of 1824, while in the afternoon hours it rises towards the curve of the warm year 1825, thus displaying, in the summer season, the character of an American climate.

The summer curve of 1826 bears the same relation to that of 1827, keeping below it in the morning till about 11 o'clock, when it rises high above it till 8 o'clock, when it descends till midnight.

In the winter curves, that of 1826 keeps between those of 1824 and 1825 from 1 o'clock A.M till 8 o'clock. It then rises above that of 1825, and keeps above it till 6 o'clock in the evening, when it again meets that of 1825, coinciding with it till about 3 o'clock in the morning. Hence it follows that the peculiar character of 1826 appears still more strikingly in the winter than it does in the summer season.

The winter curve of 1826 bears a different relation to that of 1827 in its morning branch, but a similar relation to it in its evening branch.

II. *On the Arrangement of the Monthly Curves into three separate Groups.*

By examining the daily curve for each month, it will be seen that it preserves the general form of the daily annual curve, occasionally deviating into salient and re-entering portions; but were we to delineate the individual daily curves, we should, in most cases, find the very form of a curve obliterated, and a capricious succession of elevations and depressions substituted in its place.

The most remarkable result, however, is the distribution of the monthly curves into three separate groups, namely, curves of high temperature, such as those of *June*, *July*, *August*, and *September;* curves of low temperature, such as those of *November*, *December*, *January*, *February*, and *March;* and curves of moderate temperature, such as those of *April*, *May*, and *October*.

This distinct separation of the monthly group is well seen in the Plates XV. and XVI. of Volume X., which represents them as in 1824 and 1825. In that for 1824 there is a very slight encroachment of the April curve upon that of January, but in that for 1825 the separation is complete.

In 1826 and 1827 (See Plates XXIV. and XXV.) these curves are grouped, though less distinctly, according to the same law; but, what is very remarkable, the curve for January 1826 is entirely thrown out of the cold group, and in consequence of the extraordinary cold which prevailed in that month, its curve is as far separated from those of the winter group, as any one of the groups are separated from each other.*

III. *On the Determination of the Two Hours of the Day when the Mean Temperature occurs.*

Previous to the establishment of the hourly Register at Leith Fort, nothing was known respecting the times of the day when the mean annual temperature occurs. It was generally supposed to be about 8 o'clock in the morning, and Professor PLAYFAIR adopted this as the most probable result. With regard to the time when the annual mean occurred in the evening, I am not aware that even a conjecture had been formed.

* The extraordinary character of the October curve in 1827 requires to be explained. When the daily schedules for that month were sent to me from Leith Fort, I was surprised to find *two* for the *same day* of October with very different numbers. Upon inquiring into the cause, I found that some of the non-commissioned officers who had voluntarily undertaken the duty of observing the thermometer, and for doing which they were liberally paid, had neglected to make the observations, and had filled up the daily schedules with false numbers. It is obvious from the curve that this fraud was committed by the person who made the afternoon and evening observations.

It is interesting to observe how little effect these erroneous observations have had upon the general results for 1827, when compared with those of other years.

	Hours of Morning and Evening Mean Temperature.	Critical Interval.
In 1824 it occurred at . . .	$\left\{\begin{matrix} 9^h\ 13^m \text{ A.M.} \\ 8\ 26 \text{ P.M.} \end{matrix}\right\}$	$11^h\ 13^m$
In 1825, ...	$\left\{\begin{matrix} 9\ 13 \text{ A.M.} \\ 8\ 28 \text{ P.M.} \end{matrix}\right\}$	11 15
In 1826, ...	$\left\{\begin{matrix} 9\ 7 \text{ A.M.} \\ 8\ 27 \text{ P.M.} \end{matrix}\right\}$	11 20
In 1827, ...	$\left\{\begin{matrix} 9\ 12 \text{ A.M.} \\ 8\ 23 \text{ P.M.} \end{matrix}\right\}$	11 11
	Mean,	$11^h\ 15^m$

The mean of which is

$9^h\ 11^m$ A.M. and $8^h\ 26^m$ P.M.

The interval between the morning and evening mean temperature has been called the *critical interval*, which at Leith Fort is $11^h\ 15^m$, and which, there is reason to believe, is a fixed quantity. The equality of these numbers in four different years is very remarkable, the deviation of each from the mean not exceeding 4^m.

Although the hours of mean temperature vary in different latitudes, and at different heights above the sea, yet the critical interval seems to be a fixed quantity everywhere, as appears from the following table:—

At Padua, .	$11^h\ 14^m$	At Philadelphia, .	$11^h\ 20^m$
At Appenrade, .	11 14	At Belleville, .	11 14
At Inverness, .	11 13	At Trincomalee, .	11 5
At Tweedsmuir, .	11 15	At Kingussie, .	10 44

The mean of which is $11^h\ 10^m$, differing only 4^m from the Leith result.

The determination of the times of mean annual temperature gives us the two best hours for recording the indications of the thermometer, namely, $9^h\ 11^m$ A.M. and $8^h\ 26^m$ P.M.; for if any of the observations is accidentally omitted at one of the hours, the mean of the remainder will approach nearer to the mean temperature of the year than if any other pair of hours had been taken and similar omissions made.

Another advantage of this determination is, that the mean temperature of the year may be obtained with great accuracy from a single observation made every day at one of the hours of mean temperature.

If we examine the annual, or even the monthly, curves, it will be seen that the ascending, or morning branch, is more regular in its progression than the descending, or evening branch, and therefore a single observation made at the time of the morning mean is preferable to one made at the time of the evening mean.

This regularity in the morning curve has been observed in other phenomena, but especially in atmospherical polarisation, and the cause of it has been explained by Dove and Rubenson.*

* *Memoire sur la Polarisation de la Lumiere Atmospherique*, p. 86, note.

The hours of mean temperature have a considerable range in the monthly curves, varying in the morning from half-past 8 to half-past 10, and in the evening from 7 o'clock to 9.

IV. *On the relation between the Mean Temperature of the Day, and that of any single Hour, or pair of similar or homonymous Hours.*

It was long the practice of meteorologists to observe the thermometer at *two* convenient hours, so that if the one gave a temperature greater than the mean, the other might give a temperature as much less, and in this way several registers were kept with considerable accuracy. The hours of 10^h A.M. and 10^h P.M., suggested by the Rev. Dr GORDON, were frequently used, and gave a result nearer to the mean of the *maximum* and *minimum* than any other pair of convenient hours.

Upon computing the mean temperature of every pair of similar or homonymous hours, I found, as shown in the following Table, that they differed very little from the mean temperature of the 24 hours :—

Hours of Observation.		Diff. from Mean Temp. of Day in Thousandths of a Degree.	
		Leith.	Inverness.
5^h A.M. and	5^h P.M.	−0·134	−0·434
6	6	−0·281	−0·543
7	7	−0·372	−0·552
8	8	−0·421	−0·396
9	9	−0·285	−0·113
10	10	−0·086	+0·174
11	11	+0·176	+0·374
12	12	+0·374	+0·555
1	1	+0·367	+0·550
2	2	+0·366	+0·389
3	3	+0·252	+0·173
4	4	+0·059	−0·175

Hence it appears that the defect or excess of the mean temperature of any pair of similar hours, when compared with that of the 24 hours, is always in the Leith observations less than *half a degree*. It appears, also, that the mean of 4^h and 4^h approaches nearest to the daily mean, and 10^h and 10^h next to it.

I have added to the above Table the results of the Inverness hourly observations. The deviations are very slightly greater, but the law is the same; and it is interesting to observe the interchange of the signs at 10^h and 10^h, and 4^h and 4^h, a proof of the singular equality between the mean temperature of the day, and half the sum of the mean temperature of these hours.

In speaking of this law, as given in the Report upon the Registers for 1824 and 1825, HUMBOLDT says,—

"We are surprised, at the first glance, by the generality of this law. The *homonymous* hours are very inequally distant from the hour of the *maximum* of the daily temperature. . . . . It is a thing truly remarkable, that from the

mean of two ordinates, we may deduce the mean temperature of the whole year; that is, the mean of all the horary ordinates."

As meteorological registers have sometimes been kept only once a day, it is desirable to ascertain the relation of the mean temperature of each hour to that of the day. In the following Table, I have given the results for 1826 and 1827, and also for 4 years, from 1824 to 1827 inclusive:—

Hour.	1826.	1827.	Mean of Four Years. 1824–1827.
1 A.M.	−2°·552	−1°·706	−2°·131
2	−2·903	−2·015	−2·396
3	−3·179	−2·298	−2·658
4	−3·228	−2·308	−2·793
5	−3·314	−2·316	−2·844
6	−2·943	−2·011	−2·545
7	−2·335	−1·524	−1·956
8	−1·393	−0·853	−1·180
9	−0·121	−0·096	−0·760
10	+0·970	+0·647	+0·777
11	+1·939	+1·504	+1·702
12	+2·746	+2·088	+2·463
1 P.M.	+3·256	+2·440	+2·865
2	+3·490	+2·614	+3·125
3	+3·473	+2·536	+3·135
4	+3·411	+2·353	+2·927
5	+3·065	+2·028	+2·576
6	+2·447	+1·433	+1·984
7	+1·442	+0·845	+1·211
8	+0·383	+0·350	+0·362
9	−0·460	−0·304	−0·410
10	−0·964	−0·852	−0·949
11	−1·432	−1·044	−1·351
12	−1·798	−1·318	−1·713

From this Table it appears, that the mean annual temperature of any hour never differs more than 3½° from the mean temperature of the day for the whole year. The very same result was obtained from the Register of 1824 and 1825.*

V.—*On the Parabolic form of the Four Branches of the Annual Daily Curve.*

In the report upon the Register for 1824 and 1825, I have shown that the four branches of the annual daily curve approach so nearly to Parabolas, that the greatest difference between the observed and calculated temperatures is only *a quarter of a degree of* Fahrenheit. The following Table contains the calculated temperatures for 1826 and 1827, and the difference between them and the observed temperatures:—

* Edinburgh Transactions, vol. x. p. 387, 388.

	1826.	Difference.	1827.	Difference.
Mean	48·468	...	48·423	...
	48·055	0·047	48·056	−0·063
	47·375	−0·129	47·522	−0·049
	46·786	−0·250	47·070	−0·309
	46·287	−0·383	46·700	−0·405
	45·879	−0·037	46·413	−0·304
	45·562	−0·003	46·207	−0·201
	45·335	+0·046	46·084	−0·041
	45·199	−0·041	46·043	0·000
Min.	45·154	−0·000	46·131	−0·024
	45·345	−0·180	46·396	−0·015
	45·918	−0·215	46·836	−0·063
	46·874	−0·201	47·453	−0·117
	48·214	−0·133	48·247	−0 080
Mean	48·468	0·000	48·423	0·000
	49·616	+0·178	49·220	+0·150
	50·641	+0·234	50·015	+0·088
	51·373	+0·159	50·583	+0·072
	51·812	+0·088	50·923	+0·066
Max.	51·958	0·000	51·037	0·000
	51·874	−0·067	50·973	+0·014
	51·623	−0·256	50·780	+0·004
	51·203	−0·330	50·459	+0·008
	50·576	−0·339	50·010	+0·154
	49·861	−0·049	49·431	+0 163
	48·938	+0·087	48·725	+0·052
Mean	48·468	0·000	48·423	0·000

From this Table it appears, that the difference between the observed and the calculated temperatures for 1826 and 1827, is only four-tenths of a degree of Fahrenheit, a very little more than in 1824 and 1825.

I cannot conclude these observations, without directing the attention of the Society to the singular fact, that laws so regular as those we have been contemplating should have shown themselves after only four years of hourly observations. When we consider by how many disturbing causes the temperature at any particular instant is affected—by the winds which blow over surfaces differently heated,—by the showers which instantly cool the air,—by the interposition of clouds, now screening the sun, and now giving a free passage to his rays, and by many other causes, as capricious in their origin as they are irregular in their influence, it cannot but appear wonderful that all these effects should be so nicely balanced, as to produce a perfect compensation at every point of the annual daily curve. In virtue of this compensation, we may consider the mean annual daily curve as representing the mean daily progression of the solar heat, whether received directly from the sun, or returned into the atmosphere, by terrestrial radiation.

PLATE XXIV.

Mean Daily Curves of the six Summer and the six Winter Months of 1826 & 1827.

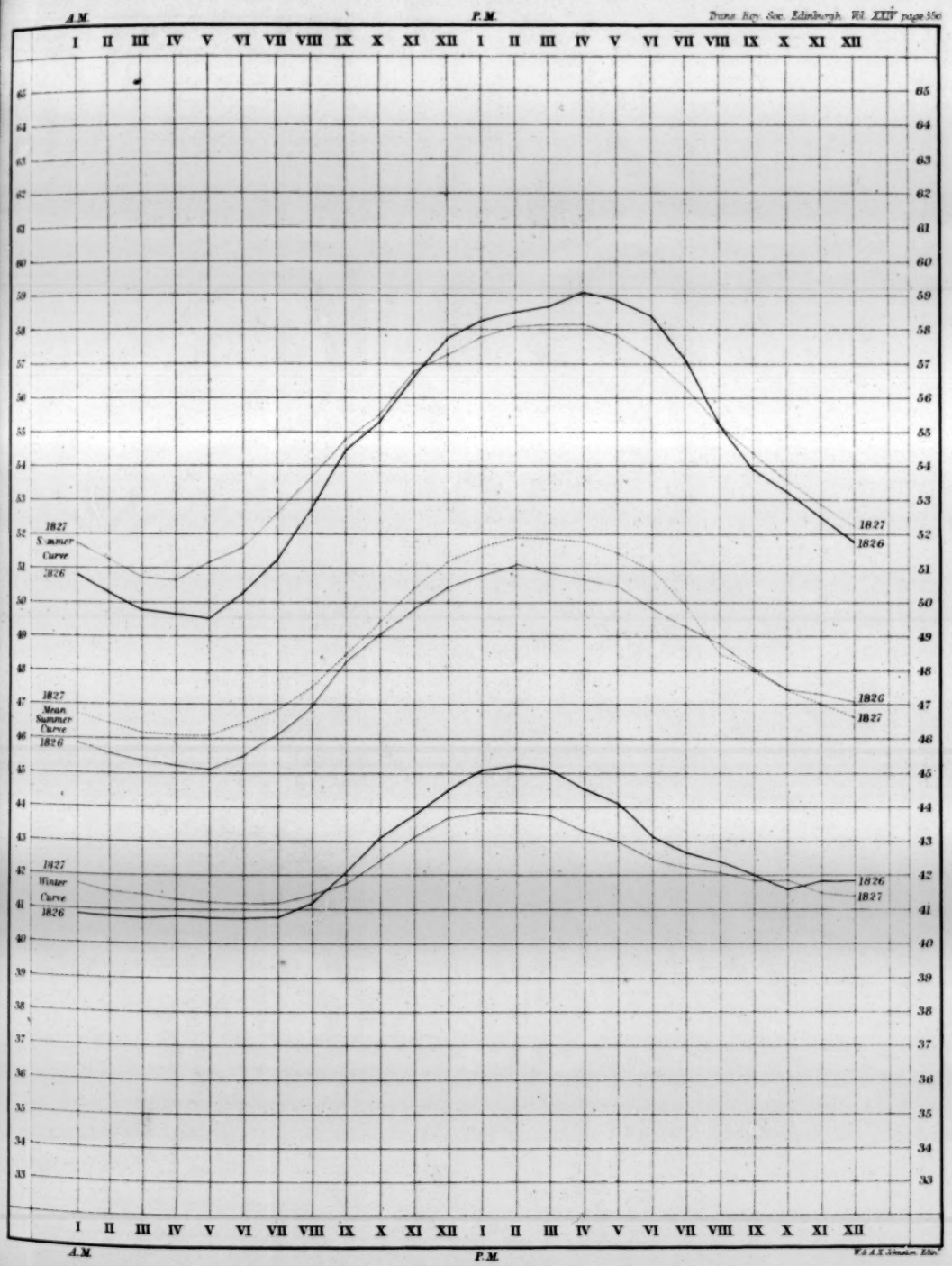
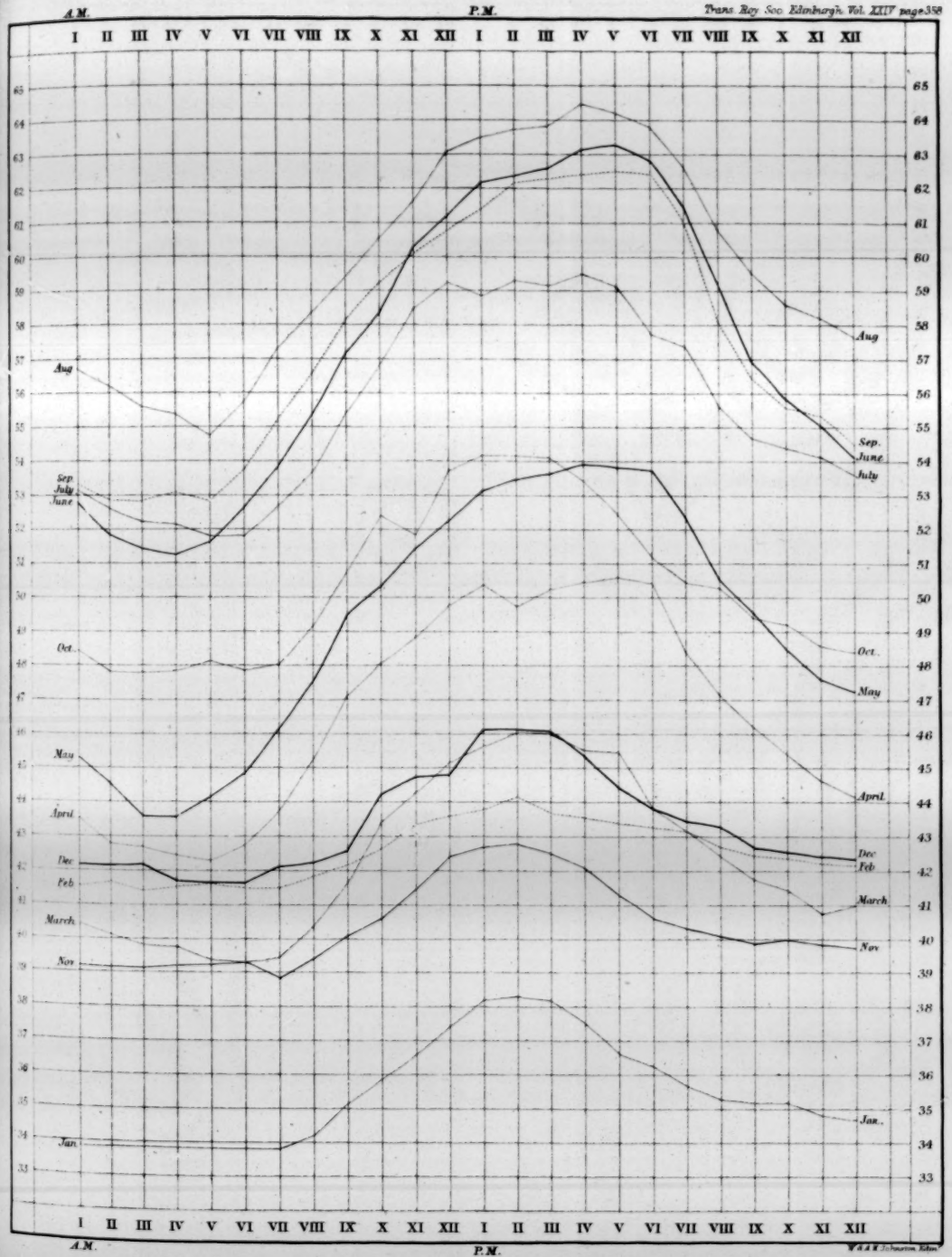


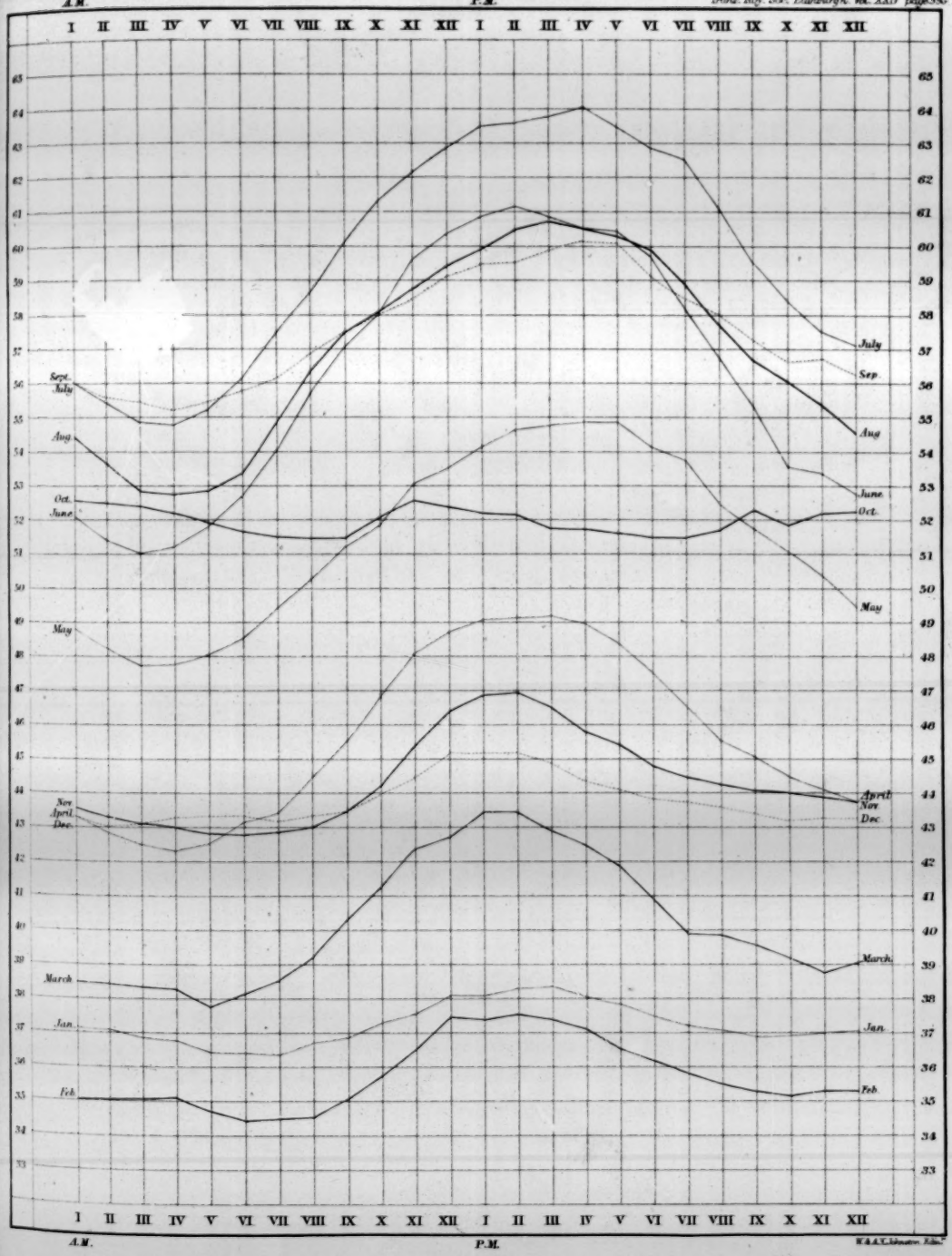
PLATE XXV-1

Mean Daily Curves for each Month of 1826.



Mean Daily Curves for each Month of 1827.

Trans. Roy. Soc. Edinburgh. Vol. XXIV page 35.



XXVIII. *On the Buried Forests and Peat Mosses of Scotland, and the Changes of Climate which they indicate.* By JAMES GEIKIE, Esq., of the Geological Survey of Great Britain. Communicated by ARCHIBALD GEIKIE, Esq., F.R.S.

(Read 19th March 1866.)

The following communication is an attempt to eliminate the geological history of our Scottish Peat Mosses. So much, however, has already been done in this matter, that the reconsideration of phenomena, for the most part well known, may appear almost a superfluous task. But, notwithstanding the essays of WALKER, RENNIE, ANDERSON, and others, in this department of geological inquiry, there is still probably much to be gathered from the same source, which shall greatly increase our knowledge of the condition of these latitudes in the ages that followed upon the close of the glacial epoch. At present, I mean to give only an outline of the subject, reserving for some future occasion a fuller statement of the facts on which the conclusions arrived at are based.

Our peat mosses appear to contain the record of certain changes of climate, which have not hitherto fully engaged attention. The evidence furnished by the buried timber has indeed been frequently considered, but not so the proofs of altered conditions which the peat itself supplies. These last, more especially, form the subject of this memoir. But any paper treating of the origin and history of our peat mosses would be incomplete, without reference to the ancient forests which they cover, and the evidence on this head has therefore been recapitulated.

It is proper to state here, that many observations on the present aspect of the peat of our hills and valleys were made conjointly by my colleague Dr YOUNG and myself, during our survey of a large portion of the Peeblesshire hills. The subject of this communication was partially sketched out by us some time ago, but the pressure of other matters latterly deprived me of my colleague's co-operation.

The phenomena revealed by our peat mosses are three-fold:—

1*st*, The buried trees, and the condition of this country at the period of their growth.

2*d*, The causes which led to the destruction of those trees.

3*d*, The present aspect of the peat mosses.

I. *Trees in Peat,—Condition of the Country at the Period of their Growth.*

It is well known, that below many peat mosses of this and other countries, the roots and trunks and branches of forest trees, and the remains of shrubs, are of common occurrence. Our Scottish mosses have yielded the oak, the pine, the birch, the hazel, the alder, the willow, the ash, the juniper, &c.; but a greater number of species are dug from the peat of more southern latitudes. No one now doubts, that the vast majority of those trees and shrubs have grown *in situ*. And as there are few parts of the country where buried trees have not been disinterred from peat or alluvium, the conclusion is forced upon us, that at some period in the past our island must have been exceedingly well wooded. Even the remote islands of the Hebrides appear to have had their groves of oak and pine. Throughout the bleak Orcades and sterile Zetland, large trees have at one time found a congenial habitat. Of the main-land it is difficult to say what district has not supported its great forests. The bare flats of Caithness, the storm-swept valleys of the Western Highlands, the desolate moory tracts of Perthshire and the north-eastern counties, the peaty uplands of Peeblesshire and the Borders, and the wilds of Carrick and Galloway, have each treasured up some relics of a bygone age of forests.

It is much to be regretted, that in noting the occurrence of the various trees which our peat mosses have yielded, so little attention should have been paid to the relative elevation of the species above the sea-level. Enough is known, however, to assure us, that the pine and its congeners enjoyed a greater range in former times than at the present day. Mr Watson gives "600 yards and upwards" as the elevation now reached by the Scotch pine. But he "has seen also small scattered examples at 800 and even 850 yards of elevation." These last, however, he thinks, had probably been planted. "But that the pine," he continues "has grown naturally on the Grampians, at an equal elevation in former ages, is rendered certain by the roots still remaining in the peat mosses of the elevated table lands of Forfar and Aberdeen, at 800 yards and upwards."* Again, in Glenavon, Banffshire, there are peat mosses, nearly 1000 yards above the sea, which contain abundant roots of the pine.† In the north of England, at the same height, "roots and trunks of very large pines are still seen protruding from the black peat."‡ Mr Watson says the Scotch pine now ranges from Perthshire into Sutherland, within latitudes 56–59°.§ But in ancient times, it must have grown indiscriminately throughout the length and breadth of Britain, as we meet with it in many of the English mosses,—those of southern as well as of northern regions.

The common oak has a similar wide diffusion in our peat mosses. According

* Cybele Britannica, vol. ii. p. 409. † Sinclair's Stat. Acc. of Scotland, vol. xii. p. 451.
‡ Mr Winch, quoted in Cybele Britannica, *loc. cit.* § Cybele Britannica, *loc. cit.*

to Mr WATSON, it is now restricted to latitudes 50–58°, finding its northern limits in Ross, Aberdeenshire, and western Inverness-shire.* But the peat mosses of more northern regions exhibit its decaying roots and branches; and nothing is more common than to meet with trunks of oak, of very large dimensions, in situations now in the highest degree unfavourable to the growth of that tree. Similar remarks apply to other species. But not only do the buried trees reach elevations unattained now by the same natural wood, they are also constantly dug out of peat mosses close to the sea-shore, of a size which rivals, or more frequently surpasses, that of their present representatives in Scotland, even when these are placed in situations most favourable to their growth.†

Submerged Trees and Peat.—At various points along the sea-coast, observers have noted the occurrence below high-water mark of tree-roots fixed in a soil, and frequently covered over with peat moss. The shores of the Orkney and Shetland Islands,‡ and the Inner and Outer Hebrides,§ furnish many interesting examples of these phenomena; and along the coasts of the mainland ‖ they are equally abundant. The "Submarine Forests" of England have long attracted attention. Few of the maritime counties do not exhibit them.¶ Around all the shores of Ireland drowned peat is of common occurrence. "At numerous points along the south and west coast it is a common practice for country people to go to the sandy bogs at dead low-water of spring tides, and dig turf from underneath the sand; and it has been equally noted in similar situations along the western and northern coasts. The stumps and roots of trees in the position of growth are found in this peat."**

Again, on the further side of the English Channel, sunk forests abound along the coasts of Brittany, Normandy, and the Channel Islands. In those regions, trees have been observed at a depth which "could not have been less than 60 feet below high-water."†† The peat mosses of Holland, with their buried trees, are constantly continued outwards, so as to extend below the level of the sea. Thus, both on the east and the west shores of the German Ocean, we meet with the

* Cybele Britannica, *loc. cit.*

† Edin. Phil. Jour. vol. xvii. p. 53. See also Phil. Trans. vol. xxii. p. 980; and the Old and New Stat. Accs. Scot. *passim.*

‡ Edin. Phil. Jour. vol. iii. p. 100; SINCLAIR'S Stat. Acc. vol. vii. p. 451; BARRY'S Orkney Islands; New Stat. Acc., *Orkneys, Sandwick.*

§ SINCLAIR'S Stat. Acc. vol. x. p. 373; vol. xiii. p. 321; Edin. Phil. Jour. vol. vii. p. 125.

‖ The Caithness coast shows submerged peat with trees, at Lybster and Reiss (from information by my colleague Mr B. N. PEACH); for notices of submarine forests and peat, see a Practical Treatise on Peat Moss, p. 150; New Stat. Acc. vol. i. pp. 16 and 243; SINCLAIR'S Stat. Acc. vol. xvi. p. 556; Trans. Royal Soc. Edin. vol. ix. p. 419. Along the shores of the Firth of Forth drowned peat occurs, as at Largo; also at several points on the Solway coast.

¶ Phil. Trans. vol. xxii. p. 980; vol. l. p. 51; vol. lxxxix. p. 145; Jour. Geol. Soc. vol. vi. p. 96; Phil. Jour. April 1828.

** JUKES' Manual of Geology, 2d edit., p. 686.

†† Jour. Geol. Soc., vol. iii. p. 238.

same appearances as are found to characterise the margins of the English Channel, and the western and northern coasts of the British Islands.

Tree-bearing Peat of Maritime Regions.—These facts, taken alone, prove a general loss of land. But, even without the evidence of the sunk forests, we should arrive at the same conclusion, after considering the nature of those trees entombed in mosses that occur close to our sea-coasts. The great size of the oak, and the dimensions attained by the pine, convince us that, during the period of their growth, those trees were far enough removed from the sea to escape its blighting influence; in other words, that the land formerly extended farther seawards. When we turn to the trees of the submerged forests, we find them in like manner characterised by their large size. Hence, we are compelled to grant a still wider area for the old sunk country.

No island of the Orkney or Shetland groups, can boast the presence of any natural trees deserving of the name. Cultivated saplings are protected by walls, but they cannot raise their tops above the level of the copestones. And yet the mosses and sunk forests of those regions abound with fallen trees, many of which equal in thickn essthe body of a man. When these buried trees decked the now bleak islands with their greenery, the land stood at a higher level, and the neighbouring ocean at a greater distance. A study of similar appearances in the Inner and Outer Hebrides will induce us to form a like opinion of the changes which they indicate. The broad barren flats of Caithness were also in ancient times overspread with a thick growth of large-sized natural wood, the peat mosses containing which pass below the sea. To have permitted this strong forest growth, we are again compelled to admit a former elevation of the land and a corresponding retreat of the ocean. And so on of all the maritime regions of Scotland.

The same inferences may be drawn from the facts disclosed by the mosses of Ireland and England. On the coasts of France and Holland, as I have said, peat dips underneath the sea, and along those bleak maritime regions of Norway, where now-a-days the pine tree will hardly grow, we find peat mosses which contain the remains of full-grown trees, such as are only met with in districts much further removed from the influence of the sea.*

Continental Britain.—Thus, over a very large area, we have proofs of a process of submergence which, to say the least, has materially diminished the extent of dry land in the north-west of Europe. From other evidence, which it is unnecessary to recapitulate here, geologists have concluded that the area covered by the German Ocean, the English Channel, and the Irish Sea, has been at no distant date in the condition of dry land. After the deposition of the marine beds of the Drift Formation, a movement of elevation ensued, which resulted in the

* From information obtained in Norway, 1865.

union of the British Isles with the Continent. The surface of this new land (overspread with an undulating and profusely dimpled covering of drift deposits), abounded with lakes and pools. We have some grounds for believing, that at this period the climate was still cold enough to nourish glaciers in the higher valleys of our mountainous regions. FORBES has conjectured,* that at this early date our country may have been in the condition of the "barren grounds" of North America. But be that as it may, there can be little doubt, that at some time, during the latest great extension of the European Continent, the upraised beds of the Irish Sea, the English Channel, and the German Ocean, were included under the folds of that broad mantle of green forest, the relics of which are so conspicuous in our peat mosses.

It is certain, that at this time the oak and the Scotch pine were contemporaneous throughout the greater part of Scotland. In the high-level mosses, the latter occurs most abundantly, while the former predominates in the peat of the lowlands. The pine does not appear to have formed any extensive forests at the lower levels of the country, although its remains have been disinterred from many lowland peat mosses.† Its choice of the more elevated regions was influenced, no doubt, chiefly by atmospheric conditions, but also in no slight degree by the nature of the soil. For underneath some low-level mosses, where oak forms the bulk of the buried timber, occasional large-sized pine trees are, as already remarked, not uncommon; showing, that where the soil was favourable, the climate offered no great hindrance to their growth. It is in the hilly regions that the pine obtains that light gravelly soil which it prefers. At the lower levels, those drift clays and earths chiefly abound, which at a former period afforded a favourite habitat to the oak.

Upon the whole, it must be conceded, that north-western Europe possessed at this period a climate more nearly approaching perhaps to that of the wooded regions of Canada, than to the climate which characterises Germany at the present time. The tough resinous wood and thick bark of our bog-pines bear emphatic testimony to the rigour of the seasons that nourished them. The present range of the pine in this country, as contrasted with its former wide diffusion, is also very significant. How changed the conditions which at one time permitted the increase of great conifers in the south of England and Ireland, but which now restrict their native growth to a limited area in the north of Scotland!

II. *Causes of the Destruction of the Ancient Forests.*

Wind.—Some of the more apparent causes of the destruction of our ancient forests may now be considered. It is remarkable, that the trees below peat often

* Memoirs of Geol. Survey.

† *Vide* SINCLAIR's Stat. Acc., and the New Stat. Acc. *passim*, and notices in various county histories, &c.

all lie one way, as if overturned by some potent agency they had met their fate at one and the same time.* The direction taken by the fallen trunks corresponds in a notable manner with that of prevailing winds in the regions where they occur; and hence a large share in the destruction of our woodlands has been attributed to storms of wind. Doubtless, many acres of forest may have been overturned in this way. But we cannot suppose the peculiar position of the buried trunks to be in every instance the result of storms. Trees are usually bent over in the direction of prevailing winds; and when any cause shall lead to their overthrow, whether it be natural decay or otherwise, the position taken by the falling trunks will be determined by the overhanging weight of their tops.†

Lightning.—Again, in our own day, large tracts of forest land in the backwoods of America have been dismantled by fire, kindled during a thunder storm. And we may believe that the resinous conifers of the ancient Scottish woods may also have suffered from the same cause. The marks of fire are conspicuous on the trees of some of our peat mosses. These appearances are to be traced chiefly to the hand of man, but we cannot quite ignore the possible agency of lightning.

Ice.—It is not unlikely also that our ancient woods may have experienced what are known in America as *ice-storms*. In winter time the trees of the American forests sometimes become so heavily laden with snow and ice that they are borne to the ground by the pressure.

Man.—That man has largely aided in clearing the woods is indisputable. Besides the evidence of his hand afforded by the charred wood under peat, we sometimes come upon marks of adze and hatchet.

The earliest historical accounts of North Britain have afforded abundant food for controversy to antiquarians, but when the geologist has gleaned together the few descriptive remarks which occur here and there, in the pages of TACITUS, HERODIAN, and others, he will find that his knowledge of the physical aspect of Scotland does not amount to much that is very definite. He will learn, however, that Caledonia was notorious on account of its impenetrable forests and impassable morasses. But the precise extent of ground covered by these woods and marshes must always be matter of conjecture. The forest land known as *Sylva Caledoniæ* appears to have stretched north of the wall of SEVERUS, but south of that boundary large forests must have existed; indeed, down to much more recent times, many wide districts of Southern Scotland could still boast of their woodlands. Of the nature of those waste plains, described by the

* Highland Society's Prize Essays, vol. ii. p. 19 (Old Series); RENNIE's Essays, p. 31; SINCLAIR's Stat. Acc. vols. iv. p. 214; v. p. 131; and xv. p. 484; New Stat. Acc. *Paisley* and *Carluke*. *Vide* also for similar phenomena in English and Foreign peat mosses, Phil. Trans. vol. xxii. p. 980; RENNIE's Essays, *loc. cit.*; Degner de Turfis, p. 81.

† *Vide* Trans. Royal Soc. Edin. vol. iii. p. 269.

ancients as full of pools and marshes, we can have little doubt, although we cannot of course pretend to point out their particular site. Those who have traversed the central counties of Scotland, must have been struck with the numberless sheets of alluvium which everywhere meet the eye, betokening the presence, in former days, of so many little lakes. In BLEAU'S Atlas, many lochans appear in spots that have long ago come under the dominion of the plough. These, however, must form but a small proportion of the lakes which have been drained since the time of the Romans. Such inconsiderable peaty lochans were not likely to merit particular mention by the Roman legionary who had gazed on the Alpine lakes, save as they became vexatious interruptions to his progress through the country; and surrounded, as many of them in all probability were, with treacherous morasses, the words of the old historians appear to have been descriptive enough of certain ample areas in the Scottish lowlands.

It seems to have been the common practice of the Romans to cut down the trees for some distance on either side a "way," to prevent surprise by the enemy. Several old "ways" have been discovered on the clearing away of mosses, and in their neighbourhood lie many trunks of trees bearing evidence of having fallen by the hand of man. The presence of Roman axes and coins leaves us in no doubt as to who the destroyers were. RENNIE has remarked,* that "of all the antiques found in mosses, by far the greatest part are Roman. No coins nor utensils of any other nation, so far as I know, at least none that would lead us back to a more remote period than the Roman invasion, have ever been discovered." He is therefore disposed to limit the origin of much, if not the greater part, of our peat to the era of the Roman occupation. It need scarcely be added, that since RENNIE wrote, many relics of human art have been disinterred from the peat mosses of Scotland and other countries, which archæologists agree in considering to be of much more ancient date than the Roman invasion. But it is quite evident, that such imbedded relics do not enable us to fix the age of a peat moss. They merely tell us, that the origin of the peat cannot date back beyond a certain period, but may be ascribed to any subsequent time.† Hence, it is impossible to say what amount of waste we are to set down to the credit of the Romans. Some authors have, perhaps, been too ready to exaggerate the damage done by the legions. The buried forests which can be proved to have fallen before Roman axe and firebrand are not many after all; but we may reasonably suppose that these form only a portion of the woods which were cleared at that time.

We have, however, what appears to be direct evidence, to show that some regions had been divested of their growing timber before the Roman period; for

* Essays, p. 69.

† It appears not unlikely that the fact of several mosses having yielded remains of undoubted Roman age, may not infrequently have weighed with local antiquarians in assigning to the same era certain relics of no marked character, which have occasionally been discovered under peat.

if SOLINUS may be trusted, the Orcades were, in the days of the Romans, bare and bleak as they have been ever since. He says, "Numero tres, vacant homine, non habent silvas, tantum junceis herbis inhorrescunt, cætera earum nudæ arenæ et rupes tenent." A patriotic Orcadian might insist that the statement "numero tres" renders what follows untrustworthy; and perhaps he might prefer the testimony of OSSIAN, who, in his poem of Carric-thura, says of some island in the group, "a rock bends along the coast with all its echoing wood." According to TORFAEUS (historiographer to the King of Denmark),* the condition of the Orcades in the year 890 agreed with the description given by SOLINUS.† For at that time EINAR conferred a great boon upon his countrymen by teaching them the use of peat for fuel, *enim in Orcadibus non erant sylvæ*. Yet it is well known that the peat mosses of the Orkneys, and even those of Zetland, contain the remains of considerable trees.

The limits of this communication will not permit me to consider in detail accounts of the condition of the Scottish forests in times subsequent to the Roman period. Any reference by the chroniclers to the state of our woodlands is only incidental, and perhaps not always to be relied upon. It is interesting, however, to learn from BOETHIUS, that the *horrida Sylva Caledoniæ* had in his time become mere matter of history.‡ He further tells us, that Fifeshire had formerly been well wooded (in the times of some of his early Scottish kings); but "it is now," says his old translator, "bair of woddis; for the thevis were sometime sa frequent in the samin that they micht na way be dantit, quhill the woddis war bet down."§ Again, BOETHIUS describes the island of Isla (whose peat mosses contain roots and trunks of trees) to be an island rich in metals, which could not be wrought on account of the want of wood.‖

After the period to which BOECE refers, any allusions to the aspect of the country are best sought for in cartularies and such records. For the rights acquired by monasteries over various forests throughout the country, these cartularies afford abundant evidence. CHALMERS¶ has enumerated many instances of special grants by kings and barons "of particular forests in pasturage and panage, and for cutting wood for building, burning, and all other purposes;" and Mr TYTLER** has added to the list. It need hardly be remarked, that the greater part of these woodlands has long disappeared. And yet, according to CHALMERS,

* TORFAEUS wrote about 1690. He was a native of Iceland, and died in 1720.

† SOLINUS is supposed to have written about A.D. 240.

‡ If this had not been the case, he would surely have quoted a less ancient authority than PTOLEMY for the site of the ancient forest. *Vide* Cosmographie and Description of Albion.

§ Croniklis of Scotland, chap. xi.

‖ BELLENDEN'S version of the passage is characteristic. He says, Isla is "full of metallis, gif thair wer ony crafty and industrius peple to win the samin;" but he quietly drops all allusion to the want of wood in the island.

¶ Caledonia, vol. i. p. 792, &c.

** Hist. of Scot. vol. ii. chap. ii., third edition, and the authorities there quoted and referred to.

the old cartularies "abound with notices of forests in every shire during the Scoto-Saxon period." I have not hesitated to quote the authority of those records, and the opinions of two such learned and correct writers as CHALMERS and TYTLER. No one can deny that the evidence of the cartularies is in favour of a better wooded condition for the country than now obtains. But we must guard against the mistake of supposing that all the area embraced under the designation of a "forest" was covered with forest trees. And there can be little doubt that both CHALMERS and TYTLER read the cartularies in the light of the facts which are disclosed by our peat mosses. The trunks of pine, oak, ash, and other hard timber dug out of the mosses, were regarded as proofs that the regions indicated by the cartularies were in reality the sites of great forests at the time to which those records refer. But it is probable, nay, in many cases quite certain, that much of this buried timber belongs to a more remote period. But even with this reservation, Scotland, down to the fourteenth century, would appear scarcely to have merited the description given by ÆNEAS SILVIUS at a later date. During the civil commotions of the country, and the long wars with England, much wood seems to have been destroyed, and the gradual progress of cultivation also began to encroach upon the forest lands. Another cause which aided in clearing away the woods from some portions of the maritime districts, is to be found in the great number of salt-pans that were early established in Scotland, and the right which the proprietors usually obtained to cut the requisite firewood from the forests of the country. But although wood appears to have been the fuel commonly employed in the manufacture of salt, yet it is not unlikely that peats may also have been burned in some cases. It is certain, at least, that peat was a common enough fuel in David I.'s reign, and that, as CHALMERS says,* "petaries became frequent objects of grant to the abbots and convents during the Scoto-Saxon period." This fact ought perhaps to be looked upon as a further proof of the increasing decay of the forests.

But by far the most remarkable testimony to the bare condition of the country is furnished by the Acts of the Scottish Parliament. From the times of the First James, stringent acts were adopted by successive Parliaments,† having for their

* Caledonia, vol. i. p. 793.

† *Vide* Acts of Scottish Parliament. The more interesting acts referring to the state of the woods were passed as follows:—James I., Second Parliament, A.D. 1424; James II., Fourteenth Parliament, A.D. 1457; James IV., Sext Parliament, A.D. 1503; James V., Fourth Parliament, A.D. 1535; Mary, Sext Parliament, 1555; James VI., First Parliament, 1567, Sixth Parliament, 1579, Eleventh Parliament, 1587. It is curious to notice how, from the time of James I. the penalties imposed upon the destroyers of wood increase in severity. Pecuniary fines are succeeded in time by stocks, prison, or irons; the culprit is to be fed on bread and water during confinement, and to be scourged before parting from his jailers. The climax is reached in the following act, which became law in 1587:—"Whatsoever persone or persones wilfully destroyis and cuttis growand trees and cornes, sall be called therefore before the Justice or his deputes, at Justice Airs, or particular diettes, and punished therefore to the death, as thieves."

object the preservation of the woods. ÆNEAS SILVIUS (afterwards Pope Pius II.), who visited this country about the middle of the fifteenth century, relates, "Pauperes pene nudos ad templa mendicantes, acceptis lapidibus eleemosynæ gratia datis, laetos abiisse conspeximus. Id genus lapidis sive sulphurea sive alia pingui materia praeditum, *pro ligno, quo regio nuda est*, comburitur."* Such a statement regarding the bare condition of the country might have been thought somewhat exaggerated, for it is the testimony of a visitor from more favoured climates; but its truth is curiously illustrated by the wording of an Act of Scottish Parliament, passed in the reign of James IV.:—"Anent the artikle of greenewood, because that the Wood of Scotland *is utterly destroyed*, the unlaw theirof beand sa little: Therefore," &c.†

There are, of course, numerous traditions regarding the former wooded condition of various districts from which the trees have long since been stripped. Many of these refer to some of those woods which I have already mentioned, as being frequently named in the cartularies and similar records.

Another line of evidence is supplied by local names; but into this subject I do not enter here.

The short outline of historical facts given above seems to prove—

1*st*. That when the Romans entered Britain they found the surface of the country to some extent covered with forests, but diversified in many places with bogs and marshes.

2*d*. That to this period we must refer the destruction of some portions of the ancient forests, whose remains are dug out of our peat mosses; but what amount of damage the woods then sustained we have no means of ascertaining.

3*d*. That from the time which elapsed after the departure of the Romans, down to the eleventh century, we have no certain records referring to the state of the preservation of any part of the Scottish woods, if we except the statement of Boethius, who tells us that Fife had in great measure been divested of its forests by some of his early Scottish kings.

4*th*. That from the eleventh to the thirteenth century, and down even to later times, there appear to have been still considerable areas of forest land, the rights to which were frequently granted to ecclesiastical communities and others.

5*th*. That during these centuries much forest was thus cleared and brought under cultivation; that at the same time woods were exhausted by building and burning, more especially as fuel for the salt-works; while extensive tracts were displenished and laid waste during times of war and civil strife.

6*th*. That from the time of James I. there appears to have been a progressive decay of the remainder of the Scottish woods.

* De Europa, c. 46. † Sext Parliament, A.D 1503.

Having alluded to some of the more obvious causes which have aided in the overthrow of our ancient forests, I shall now proceed to discuss what I consider to have been the chief agents in the work of destruction. For this purpose it is necessary that the more striking peculiarities exhibited by a section of a workable peat moss should be here borne in mind.

The best *peats* are "cast" towards the bottom of a peat moss. They show a somewhat close and compact texture, so much so as occasionally to resemble coal. Above this the peat begins to lose its more compact structure, and vegetable fibres may be detected, which on a closer inspection are recognisable as those of a moss. Towards the upper portions of the section this appearance becomes still more conspicuous, and the peat seems to consist almost entirely of mossy fibres. Throughout the section long grasses may be seen, sparingly in the lower portions, but becoming more abundant as we near the top, where twigs of heather begin to mingle with them. The upper surface or crust of the peat moss (a foot more or less in thickness), seems to be made up chiefly of heather and grasses, and such plants as Polytrichum. When peat moss wants this crust, it generally shows a treacherous surface covered with moss, into which the unwary pedestrian may sink deeper than he might have expected. Small areas of this nature are not uncommon, but they may be considered as exceptional cases. Most peat mosses are provided with a crust of heath and grass. This *crust* is termed "heather-," and sometimes "hill-peat," from its common occurrence on the slopes and summits of hills, where it does not necessarily overlie true moss peat. It seldom exceeds a foot or two in thickness, and ought properly to be considered as *turf* rather than *peat*.

The compact nature of bottom peats is due to mineralisation. But another variety of peat bog appears to show that vegetable matter, the tissue of which has been nearly lost, may be deposited in a peculiar manner under water. The mosses in which this process takes place are termed in Scotland "flows," a kind of bog characteristic of the peat of the low grounds.* The surface of a flow moss is usually flat, or nearly so, frequently showing dark lochans or tarns, the appearance of which gives us the key to the history of the flow. Their examination is attended with some inconvenience, owing to the instability of the peat, which, when ventured upon, will sometimes rise and fall with a disagreeable undulating motion. The peat, in short, is a mere pan or crust spreading over and concealing

* I have, however, observed flow-mosses on the flat *col* between two hills, and they are also common enough in some valleys, where we have no reason to suppose that they mark the site of lakes. The origin of "flows" in such situations is due to the presence of springs. "Grass and weed," says Dr King, "grow rapidly at the outburst of these. In winter, these springs swell and loosen all the earth about them; the sward, consisting of the roots of grasses, is thus lifted up by the water. The sward grows thicker and thicker, till at last it forms a quaking bog." In the same manner, "flows" are often extended beyond the limits of the lakes which they cover, by the outwelling of the imprisoned water during wet seasons.

a sheet of water, portions of which are seen in the dark lochans referred to. Many flows, however, do not exhibit tarns, and these, during wet seasons, when the underlying reservoir has received the surplus drainage of the moors and mosses, are liable to swell up and burst. It is not difficult to see how the subjacent lake has acquired its covering of peat; for in the gaps of this covering we can watch the process of bridging-over the dark inky water in full operation. Creeping out from the edges of the peat, a thick growth of Sphagnum and various aquatic plants gradually encroaches upon the limits of the tarns. As this outgrowth becomes denser, rusty grasses begin to steal over its surface, and bright tufts of Polytrichum also find there a congenial soil. So the process goes on until a crust, firm enough to support such plants as cranberry, bog myrtle, and heather, eventually makes its appearance; but while the upper surface of this crust or cake of peat thus solidifies and thickens, its under portion rots and falls down as a black vegetable sediment upon the lake bottom, where it slowly accumulates, until in time the depression occupied by the lake may come to be filled up. Many of our deeper peat mosses appear to have had such an origin.

There are thus two kinds of peat—1*st*, That which is due to the continuous upgrowth from the soil of Sphagnum and its allies; 2*d*, Flow-moss peat. The mode of formation of a "flow" is sufficiently evident, but the origin of the other peat mosses cannot always be so readily made out. It is from these last that the buried trees have been dug, and hence it has commonly been thought that the fall of the trunks, by obstructing the drainage, allowed moisture to collect and form a marsh, in which bog-mosses sprung up. The overturning of the timber is thus considered to have been the proximate cause of the formation of our peat mosses. That much peat may owe its origin to such a process is certain, and several cases are on record where the changes referred to have been observed in progress. But this does not seem to have been the exclusive, or even the most frequent, cause of its formation. There are many peat mosses in which no decayed ligneous matter whatever can be detected. In the hilly districts of Southern Scotland, peat, made up almost entirely of mosses, with the usual capping or crust of heather peat, is of common occurrence, even on considerable hill slopes. While in the majority of cases, where the peat of the higher flat-topped hills in the same region is found to contain ligneous remains, the roots and branches are often of small size, indicating the presence in former times of a scraggy brushwood. Now, if bog mosses could of themselves find sufficient moisture to enable them to form peat on a slope of 25°, it is unnecessary to suppose that they must have awaited the overthrow of mere brushwood before they could begin to grow on a flat hill top. It must therefore be allowed that some peat mosses at least have originated without the aid of fallen timber to collect moisture for their support.

Those peat mosses, however, which exhibit the trunks of large trees, bearing

marks of fire, or adze and hatchet, may be considered to have had their growth materially aided, if not always primarily caused, by the obstruction of the prostrate trees. But the peat bogs which have supplied such proofs of human agency bear only a small proportion to the mosses where no such traces have been detected. In most cases, both roots and trunks tell distinctly their story of natural decay. In the many mosses which I have visited, the trees were invariably found in such a state as plainly showed that natural decay had preceded their overthrow.

Are we to suppose that the peat only began to grow after those trees had thus yielded to decay? Did the fall of the trees, by choking the drainage, only then bring about the requisite conditions for the increase of Sphagnum and its allies?

In a favourable climate, trees, which have given way before tempest or old age, are quickly replaced by seedlings, and thus the gap caused by their overthrow is gradually filled up Why then, we may ask, was not this the case with the ancient forests of Scotland? It seems strange that the death of the trees, instead of being succeeded by the appearance of another generation, should invariably give rise to a peat moss. The explanation of this anomaly ought to be attributed to a change of climate. From some cause or other, the conditions requisite for the continuous growth and succession of forest trees no longer existed to the same extent. The nature of the great trees embedded in many of our peat mosses points, as already remarked, to the former prevalence, over these regions, of a somewhat excessive or continental climate; and (following other authors) I have sought to connect this period with the continental condition of Britain that followed upon the close of the glacial epoch. Ere long certain changes ensued, with a marked effect upon the vegetation. The succession of trees revealed by several peat mosses seems to warrant us in concluding that the severity of the climate which had nourished the hardy Scottish pines began at length to give way. The most obvious cause of this change must be referred to the new geographical position of the country. The gradual separation of these lands from the continent must have been followed by as gradual an amelioration of climate. Whether, apart from the changes arising from oscillations of level, there may not have co-existed some cosmical cause sufficient of itself to have brought about an alteration of climate, can only be conjectured in the present state of the evidence.*

It is worth noting that the succession of trees revealed by some English peat

* I have confined my remarks on this subject to the peat mosses of our own country, where the appearances presented may be explained, as stated above, by a change from continental to insular conditions. If, however, the alteration of climate referred to was also in great measure due to cosmical causes, the proofs are no doubt to be found in continental peat mosses. As I do not know these turbaries from personal observation, I am unable to say whether the greater proportion of their buried timber has fallen from natural causes or otherwise. It may be surmised, however, that marks of natural decay will probably occur most abundantly in the maritime regions.

mosses does not quite tally with that which is said to characterise the peat of Denmark. In the Danish peat mosses the pine lies at the bottom, and is succeeded in ascending order by the oak and beech. But in the bogs of England, oak and pine occur, as in Scotland, on the same horizon, and in such a way as to show that they must have grown contemporaneously in the same forest, the pine occupying the higher levels and more gravelly soil. Above the oak and pine we often find a *second* stratum of timber, consisting chiefly of birch and hazel. When, over this, we come upon a *third* layer, its prevailing wood is generally alder*. Occasionally, however, pine trees are met with in peat mosses at a lower level than oak.† While it is not denied that in this succession of trees we may have evidence of certain changes of climate, we ought to be careful that we do not attach too much importance to what may in many cases be only a local accident. The succession of trees may sometimes be explained by a change in the nature of the soil alone. Thus, in some of those clayey depressions in the drift, which have been occupied at one time by the oak, we have evidence of a subsequent irruption of fresh water converting the grove into a marsh. When the oaks had succumbed to these changed conditions, we find them succeeded in place by some other species, such as the alder or willow: from which it does not seem necessary to infer more than a mere local change of circumstances. This peculiar succession of trees, however, appears to have so frequently recurred in the peat mosses of England (if not in those of Scotland), that we are forced to conclude that phenomena so general in their appearance must be due to some common and widely acting cause.

But, apart from the evidence supplied by a succession of trees, the geological history of the peat mosses themselves is conclusive upon this point. The phenomena they present indicates the former prevalence of an extremely humid climate. During the continental period the atmosphere must have been moist from excess of vegetation, but in the succeeding or insular condition this humidity appears to have greatly increased. At what time such a climate first began to characterise these regions, it is of course impossible to say; but probably long before the complete submergence of the area now covered by the German Ocean, those changes had already been set in progress, which, in the course of ages, were to result in the formation of many, if not by far the greater portion, of our peat mosses.

The most continuous sheets of peat occur on the west side of our island, and this fact is to be connected with the greater rainfall of the west as compared with that of the east coast. It was over this rainy region that peat would first begin

* *Vide* Timber Trees, *Society for Diffusion of Useful Knowledge*, p. 32.

† Mr Sainter, in a letter to my colleague, Mr A. H. Green, describes the Danes' Moss, a large peat bog near Macclesfield. In this moss, he says, "the Scotch fir is found at a depth of about 20 or 25 feet. A few feet above this lies the larch, and then in ascending order come the oak (*Quercus Robur*), birch, hazel, alder, and willow." This moss occupies a depression.

to spread itself. In the lakes and pools of the country, *Sphagnum* and other aquatics had luxuriated from an early period, covering the surface of the water with an unstable crust, which often-times gave way beneath the weight of large quadrupeds, such as the Irish deer. Many old lake hollows, long since filled up with peat, teem with the relics of this and other animals of the period; but the process of filling up these ancient basins is still in many cases incomplete. Flow-mosses and quaking bogs have yet to pass into the condition of solid peat. With the increasing humidity of the atmosphere, bog mosses were no longer to be restricted to lakes and pools. As the forest trees decayed along the exposed sea-coasts, the mosses crept over their prostrate trunks, and, spreading inland, began to invest those trees that had not yet succumbed to the inclemency of the climate. On the moist hill-tops the same increase of mosses went on, as throughout the country generally there were doubtless many other spots where the same conditions were followed by like effects. The stems, invested by the wet mosses in their upward growth, gradually rotted away, and were thus ready to yield to the first strong wind. So the destruction proceeded—the mosses ever widening their area, creeping outwards and downwards from the misty hills, and inland from the storm-swept coasts.

This mode of accounting for the decay of the trees seems to be warranted by the state in which they have been preserved. RENNIE has remarked, and the truth of the statement is easily confirmed, that the "upper side or surface of trees found in moss is uniformly most consumed; an oak may be often seen where the upper half is so consumed that only the semi-diameter of the tree remains." He subsequently says that when the bark has been preserved (which is not often), it usually adheres to the under portion of the prostrate stems. Thus, at the time these trees fell, a certain thickness of mosses had formed, which received and protected from decay the under portions of the stems, but the upper semi-diameters had rotted from exposure before the advancing mosses could reach them. Dr RENNIE, however, was of opinion that this partial preservation of the buried trees "is a proof that the tree when it fell on the spot had been half-immersed in the mass of ruins, and that half," he adds, "has been thereby preserved entire." Again he says: "Some trees in every forest decay through age; it is probable whole forests may have suffered this fate, especially where a subsoil of *moss* had been formed around the roots of the trees during the period of their growth. Chilled by this means, not only the bark but the white wood would crumble away before the trees were finally overthrown." By the expression *subsoil of moss*, Dr RENNIE means the vegetable mould resulting from the decomposition of fallen leaves, fir cones, and branches, which in another place he shows us might oftentimes form a considerable thickness of peat. Now, it is quite true that at the bottom of many peat mosses we have a certain thickness of what has been called *stratified peat*—the vegetable mould that collected underneath the

ancient forests. It is remarkable, however, that this kind of peaty matter is in general so much decomposed that frequently merely the roots of the old trees can be detected. Leaves, twigs, branches, and trunks have usually mouldered away; it is chiefly in its upper portions that this stratified peat yields such remains. And their preservation is due to the protecting properties of the overlying true moss peat. It may be doubted, therefore, whether this vegetable mould has in itself any antiseptic qualities. When trees are overturned in a forest, it usually happens that the portions next the soil are the first to decay. Dr WALKER has described* the destruction of Drumlanrig Wood in the year 1756. The overturned trees, he tells us, being allowed to rot on the ground, ripened into what he has termed "peat-earth." The same author has given an account of the moss of Strathcluony,† as showing distinctly, first, at the bottom, roots of fir fixed in a subsoil. Above these came three feet of "peat," then another set of fir roots, covered over by yet other three or four feet of "moss." Again, atop of "these last roots, which were situated three or four feet deep in the moss, an aged fir was growing on the surface." By *peat* and *moss* Dr WALKER gives us to understand that he means the vegetable mould resulting from the growth and decay of the trunks and branches. These, it would seem, had *entirely decomposed.*

With regard to the chilling effect of this vegetable mould upon growing trees, it may be questioned whether it is likely to produce the effects which Dr RENNIE attributes to it. In the American forests it often attains a considerable thickness, yet the trees of those regions show no signs of decay in consequence. Moreover, the succession of fir stumps with intervening peaty matter, at Strathcluony and other places, shows that the mould could not have the destructive effect supposed. For if it had brought about the death of the first tier of trees, it would not surely permit the growth of a second, and even of a third, generation.

The peat which encloses the fallen trunks of our bogs will be found, when carefully examined, to show fibres of moss, and sometimes to resemble closely the overlying true moss peat. In its upper portions it is certainly not always a heap of decaying leaves and ligneous matter. We must not forget that the weight of a large tree would crush down the few feet of soft pulpy moss on which the trunk fell. Twigs and branches would soon crumble away, and the mould resulting from the partial waste of the stem itself would mingle with the surrounding peat moss; so that it might well appear, when the tree came to be dug up, as if the peaty matter on which it rested, and by which it was partially enveloped, were composed of its own decomposed substance, differing, as in some degree it must, from the overlying pure mossy peat.

* Essay on Peat, Highland Society's Prize Essays, vol. ii. p. 19 (Old Series).

† *Idem*, p. 20. *Vide* also, for examples of the same phenomena, Irish Bog Reports, vol. ii. p. 61; Transactions of the Geological Society (Second Series), vol. ii. p. 140.

In hill mosses, where the buried trees are of small size, the bark, when preserved, not infrequently adheres all round the stems, as if the mosses had been enabled to cover over the prostrate trees before decomposition had well begun.* Again, both in high and low-level mosses, the stools of trees have not uncommonly retained their bark, even when the trunks and branches in their neighbourhood have greatly decayed. The wet plants seem thus to have protected the under portion of the stem, while at the same time they killed the tree. When the main mass of the trunk eventually gave way, it fell to the ground stripped of its bark. But upon this last appearance much stress cannot be laid, because we should expect that when old age shall overtake a tree, its lower portions will be the last to go; and consequently, long after the other parts of the trees have mouldered down, the stools might still resist decay, and by and by come to be buried in a good state of preservation.

It is well known that the stools or stumps in many mosses are frequently all of one height. When the overthrow of the trees has evidently been the result of natural causes, this appearance is inexplicable unless we call in the aid of the bog mosses in the manner stated. The old statist of the parish of Kilbarchan, in Renfrew, tells us† of the buried trees in the mosses of his district, that "the stumps are standing in their original position. The trees are all lying from south-west to north-east. "How an oak tree," he says, "could break over at that particular place I never could understand. But we may be allowed to form a conjecture, that before the tree fell, the moss had advanced along its stem, and rotted it there."

In those mosses where the rooted stumps are of unequal height, we may account for their overthrow in the same manner. In the case of the Kilbarchan trees, *wind* may have been the immediate cause of their downfall. But when, left to themselves, the doomed trunks were no longer able to support their own weight, and began to give way, they would not all do so at the same time. Some species might die and fall to ruins, while others still lived on, and the more massive trees would long tower over their less sturdy brethren. As the mosses were all the while adding to their thickness, the trunks, as they successively yielded, would break off at different levels, while their fallen portions would be buried at slightly different depths, the pressure of the fallen trees tending to squeeze down the soft underlying moss.

Nay, it has even happened that mosses have overtopped the trees which they have killed. In the moss of Curragh, Isle of Man, large trees have been met with standing erect, with as much as 20 feet of peat above them. The same pheno-

* It must be remarked, however, that a large proportion of the trees here referred to consists of birch, the bark of which is usually obtained in a good state of preservation, although the wood itself may have entirely decayed.

† Sinclair's Stat. Acc. vol. xv. p. 484.

mena are said to characterise "many of the deepest mosses of the continent." Thus the chief cause of the destruction of our ancient forests appears to have been a change of climate. The altered atmospheric conditions were not only directly unfavourable to the propagation of forest trees over certain large districts, they also brought about a vast increase of marsh plants. To the chilling effect of the wet bog mosses in their upward growth must be attributed the overthrow of by far the greater portion of the buried timber in our peat bogs.

As the origin of this change carries us back far beyond the earliest dawn of history, it follows, that much of the peat and buried timber of our country may be of great antiquity. And, indeed, in the case of many mosses, we seem more likely to err in ascribing too recent than too early a date to the period of their formation. We cannot estimate the time which has gone by since our western islands supported those timber trees, the remains of which are dug out of the mosses. It is highly probable that at this early period those islands were joined with the mainland, and shared a continental climate. To the same date we may refer much of the buried timber of the Orkney and Shetland Islands. Again, the more elevated peat mosses of our country must have been among the first to be formed; for, as already remarked, any change from a continental to an insular state, would tell first upon the trees that grow along the sea-board, and at the higher elevations of the land. It seems very reasonable therefore to conclude that, long before the Romans set foot in Britain, the growth of peat moss and the overthrow of timber had made considerable progress; that, in short, the *Sylva Caledoniæ* was but the relics of that great forest which in former ages had spread all over the area of these islands and the German Ocean.

I cannot enter into the vexed question of the probable area of wooded land in Scotland at the time of the Roman invasion, but there can be little doubt that had our peat mosses never yielded any remains of former forests, very little could now be said for the wooded condition of Scotland in the days of the Cæsars. The buried trees are of no avail as evidence, unless we can prove them to have been overturned since the times of which TACITUS writes; and it is surprising how few tree-bearing or other peat mosses can be shown to be of this or later dates. By far the greater number belong to much earlier times. In the few historical notices given above of the state of the Scottish woods in ages subsequent to the departure of the Romans, no small share in the work of destruction has been assigned to man himself. How far his efforts were seconded by an adverse climate it is impossible even to conjecture. But that to some extent they may have been is not unlikely, from the fact that some of the buried trees, belonging to peat of Scoto-Saxon and still more recent dates, have evidently fallen from natural decay; while, in many districts, which record and tradition allow to have been at one time well wooded, the indigenous wood of the country either refuses to grow, or at best attains to but a sorry size.

III.—*The Present Aspect of the Peat Mosses.*

A glance at the present aspect of our peat mosses will convince any geologist that this formation has not only ceased to spread, but is in most cases rapidly disappearing. The moisture which in former times afforded it nourishment and support, has now become its chief enemy. Every shower of rain, every frost, gives fresh impetus to the decay; and leaving altogether out of account the operations of agriculture, we can yet have no doubt that natural causes alone would, in time, suffice to strip the last vestige of black peat from hill and valley. These remarks might be illustrated by examples drawn from any peaty district of Scotland, did space permit, but a general description of the appearances presented by dead peat is all that can be attempted.

The surface of peat which has ceased to grow is usually covered with short scrubby heath and rusty grasses, but frequently in so sparse a manner, that every here and there the black peaty mould peers through. Nay, in many cases the decomposing peat lies exposed and bare, with not a tuft of heath or blade of grass to be seen. Peat mosses of this description are not confined to any particular locality or situation. They occur generally throughout the country, and may be found on hill tops, on hill sides, and in valleys.

The peat of a hill-top usually shows a most ragged and wasted aspect.* Innumerable winding gutters of variable breadth intersect it in all directions. These widen as they approach the circumference of the peat towards the brow of the hill, where, at their outlets, they are often yards across. When the hill-slopes have retained any of their peaty covering, it is usually still more cut up than that on the hill top. These natural channels or drains are due to the wasting action of running water, assisted by winter's frosts. The peat is dead, and, like the upraised coral reefs of the South Seas, wears rapidly away at the touch of the atmospheric agents. Year by year, the little channels are eating their way back into the heart of the peat, and the process of destruction has often been carried so far as to have left merely a few irregular-shaped segments of peat scattered here and there over the top of the hill.

* Few regions exhibit the decay of hill-peat to better advantage than the Moorfoots and Peebles-shire hills. The summits of the Moorfoots may be well described as a wide platform or table-land, out of which valleys have been scooped by rivulets and streams. Standing on the shoulders of one of the hills at the head of the Leithan Water, we see stretching out before us what appears to be a wide-spread and undulating peaty plain. To the wanderer across these hill-tops, the deception is often for some time complete, till of a sudden he finds himself on the brink of a green grassy bank, which slopes steeply down to a brawling stream, and again rises to a corresponding height on the other side. The peat stopping thus abruptly where the ground begins to descend, has the appearance from below of a black wall running continuously along the brow of the hill. This is especially conspicuous in the valleys of the Leithan and its tributaries, and also at the heads of the Luggate, the Heriot, and the Gladhouse Waters. The higher grounds of the Border counties also show peat in every stage of decay. The same appearances characterise the flat-topped hills of Carrick, which overlook the broad undulating moors of Wigton and Kirkcudbright.

The peat of the lower grounds attains to a much greater depth, and has less of a denuded and wasted aspect than that of the hilly regions. In many spots, indeed, Sphagnum and other peat-forming mosses seem to thrive well. But wherever the slope of the ground suffices to create a drainage, the peat crumbles away. Even where the peat occupies a hollow or plain, where the drainage must be weak, the decay of the moss has often been observed making rapid progress. There are, perhaps, but few bogs in Scotland which do not exhibit what are known as *moss-hags*—holes usually filled either with soft black mud or dry peaty mould. These moss-hags are the result of denudation, and increase in width by the gradual mouldering away of the surrounding peat. Sometimes a system of natural drains or gutters connects the different holes; but many of these show no apparent outlet, and the water collected in them escapes, by slowly soaking through the moss, or by creeping outwards between the peat and the soil.

The peat mosses of Scotland are thus only a wreck of what they have once been. The out-growth of peat has ceased to be general. Here and there mosses continue to increase in sufficient abundance to form that substance; but this increase, such as it is, is far exceeded by the general rate of decay. The peaty covering is almost everywhere full of holes and winding channels, a sure sign that the bogs have ceased to combat against the denuding powers of rain and frost. Their upper surfaces are no longer overspread with Sphagnum—a hard crust of heath and grasses caps them instead. All this points to a decrease in the humidity of our climate. It would be interesting to ascertain at what time a diminished rain-fall first began to tell upon the growth of peat. Dr ANDERSON has remarked: "It is well known that mosses, large ones especially, are universally bare on the surface (I mind not trifling exceptions), or covered with a few cows of heather only; and it is as well known, that they have been in the same bare and unproductive state since the earliest accounts of them have been preserved." But the early accounts to which that author refers do not enable us to form a definite notion of the nature of the surface of our peat mosses in olden times. We can only gather from them that moss-troopers enjoyed a certain immunity from the visits of troublesome strangers who, not knowing the secret paths across the mosses, dared not trust themselves to the treacherous surface. Some of the bogs alluded to were, no doubt, flow-mosses, which are equally impassable at the present day by any body of men, either on foot or horseback. It seems impossible, however, to learn from historical records at what time those peat mosses, which cover over the ancient woods, first received their crust of heath and grass, and then began to break up into hags and channels. We know that the Covenanters of the seventeenth century employed the holes in the mosses as hiding-places. Many traditions to this effect are floating about the moory districts of Carrick; and the cairns and memorial-stones, marking out the spots

where those unfortunate dissenters were discovered and shot, confirm the truth of the traditions.

The decrease of moisture which induced the death and waste of the mosses must have been very gradual. Year by year its influence would begin to be felt,—first, in those districts which have the smallest rain-fall,—last, in hilly regions, and other places, where the rain-fall is great. Hence it is that we have still the largest display of peat along our western and south-western borders, and upon the moist hill tops and elevated valleys of the north and south of Scotland. The same may be said of England; and Ireland (which drinks most deeply of the Atlantic rains) can still show a goodly quantity of growing peat.

It has been said that the Scottish peat mosses have originally covered a much wider area than they do now. In the east, as well as in the west, great mosses once existed, which have now either disappeared or are fast disappearing. The peat on the tops of the Lammermuirs, the Moorfoots, the Peeblesshire hills and other hilly districts in the same region, is evidently the remains of a broad peaty mantle, which at one time stretched down many of the hill sides, and was continuous with the mosses of lower levels. Segments of this old covering may still be seen lying on some hill sides, and looking as if they had broken off and slipped down from the wasting cap of peat on the top of the hill. The alluvium of the same regions often shows alternations of sand and clay with peaty matter, borne into its present position from the hill sides and upper parts of the valleys.

I have often had occasion to notice, that of a peat-covered hill the least ragged portion of the mantle will invariably face the direction whence come the rainy winds. This is very well seen in the hilly districts of South Carrick and Galloway. In that region, the hill-slopes looking to the south-west may have a thick, continuous coating of peat, while the peat on the opposite side is seamed with innumerable winding channels, as if it had been violently rent in pieces.

All these appearances convince us that the climate of the country has become less humid. We must look to the drainage works of the agriculturist, and consider whether these are sufficient to account for this change. But after allowing that much may be done by a good and extensive system of drainage to affect a climate, we may, perhaps, doubt whether the changes which have rendered our atmosphere less humid can be assigned exclusively to this cause. Such considerations are not, strictly speaking, within the geologist's province. I may, however, state in conclusion some of the reasons which have led me to suspect the existence of some cosmical cause, apart altogether from the agency of man.

Drainage operations, although carried on very generally throughout the country, are yet not everywhere effective. Some districts are much better drained than others; and there are still portions of the country to which this important work has not as yet been extended. It is only within recent years, indeed, that the drainage of peat lands has met with the attention it merits. And yet almost

everywhere in Scotland death and waste have assailed the peat mosses, showing that the decrease of moisture which has brought about this result does not arise from any mere local cause, but is characteristic of the general climate of the country. To this we must add the fact, that our peat mosses had begun to moulder away long before anything like the present systems of drainage had been adopted.

As we proceed from north to south, we find that the peat has not only suffered a larger amount of denudation, but its substance has been pulverised or "consumed" in a greater degree. Thus, the peat of England, especially in the southern districts, is more consumed or decomposed than that of the Scottish mosses. In other words, a longer time has elapsed since the English peat ceased to grow, so that having been exposed during this period to the power of the atmosphere, it exhibits stronger marks of waste than the peat of Scotland. The French peat is said to be still more consumed than that of England; and indeed, it may be remarked generally of the peat of southern latitudes, that it has crumbled away to a much greater extent than that of more northern countries.

The change of climate indicated by the wasted aspect of peat moss thus appears to have shown itself first along the southern limits of that formation in Europe. It then slowly extended its influence in a northward direction, meeting in its course with many modifications, such as must arise from local circumstances. Chief among these was the configuration of the land—the peat of low-lying districts dying out more quickly than the mosses of higher levels, where any diminution of moisture is last to be appreciated. In the same manner, the track of the rainy winds on the west and south-west coasts have also marked out a region where we now meet with less waste among the mosses than in those of other districts. But as the effects of such a cosmical change must be so blended with the results brought about by the progress of cultivation, we can do little more than suggest the extreme probability of its existence. As it can be shown that the destruction of our ancient forests has not been primarily due to man, although in the later stages of the process he certainly played an important part, so we may suspect that the change from a humid to a drier climate has also been effected by natural causes,—but man, eagerly following nature, has outstripped her in her work, and so identified this with his own, that it now becomes hardly possible to distinguish the one from the other.

XXIX.—*A Notice of Recent Measures at the Great Pyramid, and some Deductions flowing therefrom.* An Address delivered to the Royal Society, Edinburgh, at the request of the Council, by Professor C. Piazzi Smyth, Astronomer Royal for Scotland. (Plates XXVI., XXVII., and XXVIII.)

(2d April 1866.)*

Mr President and Gentlemen,—I beg to thank you for the favourable opportunity which you have kindly afforded, and the facilities you have granted, for enabling me now to try to lay before you some short and simple account of my chief employments last winter at the Great Pyramid of Jeezeh.

My object in going there, was not to excavate, nor to collect antiquities, but merely to inquire instrumentally, and by my own individual labour, into the very discrepant, and sometimes mutually contradictory, accounts which have been published of the form and detail of that ancient monument by writers of almost all nations; and as one chief source of their unfortunate variations seems to have been the usually short and hurried character of their visits, my first care was to apply for leave, from His Highness the Viceroy of Egypt, to occupy the ground at the Pyramid with a permanent establishment, and to stay there as long as might be necessary for the work in hand. His Highness, as I am extremely happy to confess, and with the best of my thanks to acknowledge, was most liberal in his condescensions; conveyed our party, at his own expense to the Pyramids; lent us tents for the period of our stay; and sent a force of twenty men for a month to clean out the interior of the Great Pyramid, or otherwise prepare its more than classic walls for the examination to be made, and which lasted from that time uninterruptedly for a period of four months.

Of preliminaries to the instrumental inquiry, I would beg to mention, first of all,—but in a general way only as to the locality, and in reference to the fossils now on the table,—that the hill on which the several Pyramids stand, with much of the Libyan desert behind, or westward of it, is composed of limestone of the earlier tertiary formations, arranged in extensive and massive sheets of tough strata, all of them dipping a few degrees to the south-east, and richly charged with nummulites, echini, and various other fossils. From that stand-point looking northwards, you may see older strata, such as the chalk of the secondary rocks, cropping out on the distant edge of the tableland; and southwards, you

* ERRATA.

Page 394, line 2, *for* measure, *read* measures.
„ 395, last line, *for* This last important element, *read* This important density element.
„ 397, line 26, *for* it is, *read* such pound is.
„ 400, „ 15, *for* in ten, *read* in terms of ten.
„ 401, „ 4 ab imo, *for* been marked, *read* been passage-marked.
„ 402, „ 11, *after* the Pleiades, *insert* or their *lucida* „ Tauri,.
„ 402, „ 22, *after* than, *insert*, but equally primeval with,.

come upon newer formations, probably the latest of the pleistocene, where the hill surface is, in places, richer in well-preserved and almost fresh-looking cardiums and other shells than any modern sea-beach.

Throughout all these various ages of hills, however, it is important for our present purposes to know, especially as confuting *some* theories of the Pyramids, that there is no trace of igneous or metamorphic action of any kind or degree; and though large quantities of granite, greenstone, basalt, and diorite are constantly found lying about (and of which the table holds a few specimens), they can all be traced up to various monuments in the neighbourhood, whereto they were brought by ancient industry from distances of many hundreds of miles.

Secondly, and in a similarly general manner only, I would mention,—that it was easy to perceive that the Pyramids, with all their mysterious grandeur of a prehistoric age, are surrounded by tombs, often fully as old as themselves; the whole region is, in fact, an enormous burying-ground, used over and over again by several of the earlier dynasties of Egyptian polity; and since their time plundered, emptied, and ransacked to the last degree by later-empire Egyptians, Persians, Greeks, Romans, Arabs, and at last by modern Europeans, causing all one's steps occasionally to be amongst smashings of coffins and bones of men.

Yet though found among them, and often used for the same purposes, the Pyramids, as a class, are distinguished from tombs proper; for while the interiors of these are covered with writing, carving, and painting, replete with description and story upon nearly every particle of their surface, there is nothing of that kind, excepting of course the quarry marks on concealed fragments, to be met with inside the Pyramids. In the interior of the Great Pyramid, indeed, which differs even more than the others, and in a most pointed and peculiar manner from any known sepulchral arrangements, *its own* grand and solemn walls either speak not at all, or in the pure and highly-fraught language of proportions of geometrical surfaces and mathematical angles.

In the interpretation of *such* signs, hierology and literary Egyptology give us no assistance; classical authors are entirely misleading, and there is nothing for it in our case and times, but to attack with the instruments and methods of modern science, and as a scientific problem, the great practical work which bridges, at least, the last four thousand years of the world; and brings us in these latter days, face to face with men who thought great thoughts and acted nobly, more than a thousand years before Homer wrote or Agamemnon ruled.

In this view, Sir, my examinations and proceedings took the form, first, of measures of length, by means of the various rods and scales now exhibited on the table and about the room.—Second, of measures of angle, by means of the sextant apparatus, circular clinometer, and alt-azimuth instrument before you.—And, third, of measures of heat, by means of a variety of thermometers.

The individual observations made with all these instruments are numerous

enough to fill several manuscript books, and will be accessible when required; but at present I will only ask your attention to a few of the results; and these results should begin by bearing on some of the very simplest propositions that have ever been ventured concerning the Pyramid; for we cannot at first starting be too sceptical of anything like mere assertion, and must try to prove our way as we proceed.

Proposition 1.

Let this model, if you please, on the table, represent the figure of the Great Pyramid; drawing No. 1 (Plate XXVI.), a vertical section of the same through its central axis; and drawing No. 2 (Plate XXVII.), a ground plan; then, many theorists and travellers have assumed as exact, what is evidently true approximately; viz., that the base of the Great Pyramid is a *square*.

But they have only assumed, asserted, or concluded, not measured it; and meanwhile, a Dr VANSLEB has declared in his published Travels, that he could see very easily that *all* the Pyramids had invariably two out of their four base-sides much longer than the other two; and he tried to measure the amount of such difference at the Great Pyramid with a long rope. But the outside of the monument was so ruinous, and its base so encumbered with heaps, nay positive hills, of broken stones, that his efforts at measure were defeated; and yet he leaves his readers under the impression that the anomaly he had previously indicated, must have been at least a sixth or so of one of the sides.

To such a statement, then, my labours answer thus,—first, having measured again and again about the huge monument, correcting for errors of dilapidation and encumbrance of the ground as well as I could, there was shown to be no error in the length of any of the four base-sides, equal to the 80th part of one of them.

Second, during the last fortnight of our party being at the Pyramid, there came there with a following from the works of the Suez Canal, Mr WILLIAM AITON, the well-known and most energetic railway contractor of Glasgow; and he set his people digging at all the four corners of the Pyramid, until they had not only rediscovered the two corner sockets, marking the original size of the northern side of the monument, and which had been first discovered by the French *savants* in 1799, but until they had also come upon the other two corner sockets, which had never been seen by mortal eye for the last thousand years at least.

Then, all four corners of the ancient base of the Pyramid were visible at once, and were found to be clearly cut in the solid and monolithic rock of the hill; and Mr AITON'S chief assistant, Mr INGLIS, having measured every one of the four base-sides from socket to socket, but still under excessive difficulties from the encumbrance of the intervening ground, found the greatest difference of any two sides, including error of observation, not more than $\frac{1}{500}$th.

And, thirdly, I was enabled, though in a rather round-about way by reference to the Pole star, but with the magnificently powerful alt-azimuth circle before you.

to measure the angle contained between two adjacent base-sides of the Pyramid, as defined by their sockets; and found such angle to be equal to 90°, all but the small quantity of 44″; so small a quantity, that if produced by an error in the length of the opposite side, such error could be only the $\frac{1}{3600}$th part of the whole side.

Proposition II.

The next assumption has usually been, that the four sides or slopes of the Great Pyramid incline towards the central vertical axis at *equal* angles. But against such a belief, Dr PERRY has recorded in his Travels, that every one can see that each of the sides of the Pyramid inclines at a different angle, one 3°, another 4°, and another even 8°, from its fellow. There was a memorandum also handed to me before going out to the Pyramid, by a member of the Egyptian Institute in Cairo, making, from recent observations, differences of as much as 4°.

These differences, no doubt, arise to some extent from the present dilapidated and worn state of the surface of the monument, all the ancient exterior of which has been long since stripped off, and only the ruined courses of the mere internal bulk of masonry remain. Yet, nevertheless, when I tried, after a familiarity of some months with features and accidents of the Pyramid, to choose out stones above and below, very little weathered, and measure between them, with better instruments too than my predecessors had used, the difference of any two sides was reduced to 18′.

In the second place, the angles of elevation at the corners of the Pyramid being measured from the exact stand-points given by the sockets cut in the rock, the greatest difference of any one angle from another was found to be, on reducing them all to one level, only 3′.

And, in the third place, by looking about among the heaps of broken stones on every side of the foot of the Pyramid, innumerable fragments of the ancient casing stones were picked up; and all which admitted of measure, proved to have practically the same angle on whatever side of the Pyramid they were found.

The nature of the casing stones of the Pyramid may be easily gathered from the accompanying model. The great bulk of the Pyramid is constructed of coarse masonry in rectangular steps, like these which form its present exterior; but outside them a casing for the whole Pyramid was anciently laid on, thus,—first, one or two layers of smooth, and comparatively small-sized, but well-cut rectangular white stones; and, finally, a layer, rectangular within, but beveled off outside, at the general angle of the whole Pyramid.

These stones were always laid in accurately horizontal courses; and having had a number of their veritable fragments recently inserted into a horizontal section of this carefully constructed model of the theoretical Pyramid (App. II.), no difference in the outer slope of each of the stones can be detected, as dependent on the side of the original Pyramid, from which the specimen came.

Proposition III.

Our third proposition is to the effect that the angle of elevation of any one of the sides of the Great Pyramid is 51° 51′ 14″ 3. This quantity was affirmed by the late venerable JOHN TAYLOR of London, founding on Colonel HOWARD VYSE'S measures of his two colossal casing stones *in situ*. Most important too is JOHN TAYLOR'S statement, if proved to be real; for on possessing that precise angle, and that only amongst any number of possible angles, depends the power of the Pyramid to symbolize by its height and length of perimeter of base, one of the most radical and important truths in both pure and applied science, viz., the proportion of radius to circumference in a circle.

But that angle for the Pyramid, though derived from good measures, has by no means been allowed to stand unchallenged either by observers, or theorists; one of the very greatest of whom, the late eminent Baron BUNSEN, insists on 51° 20′ 25″ being the true quantity, because it results from a favourite hypothesis about the employment of the profane Egyptian cubit.

I beg therefore to report from my practical proceedings,—

First, That the mean of many measures on all the present sides of the Pyramid, dilapidated though they be, amounts to 51° 49′ nearly.

Second, The mean of the angles of nineteen fragments of casing stones, many of which you see before you, gave, on being carefully measured, 51° 54′.

Third, The angles of the corner lines of the Pyramid being measured from the sockets, and reduced to the equivalent angle of the sides, give, with an assumed probable thickness of the ancient casing near the top of the Pyramid,—the measures too having been taken with the large PLAYFAIR altitude azimuth instrument,—give 51° 51′.

And, *fourth*, There is a completely different and a new testimony to be referred to, the azimuth trenches. (See Plate XXVII.)

These are long and deep pits cut in the solid limestone of the hill, with hammer and chisel, on the eastern side of the Great Pyramid; and there is nothing analogous to them about any other of its sides, or indeed any side of any other Pyramid.

Speculation has been various on these trenches; men of architectural turn of mind have pronounced them the pits in which the mortar was mixed at the building of the Pyramid, and others of Egyptological pursuits have declared them tombs. To myself, however, they gave so eminently the impression of a laying out of angles before the erection of the Pyramid, that I set to work with the powerful discrimination of the large altitude azimuth circle to ascertain what the angles were.

Placing the instrument therefore at the very remarkable general converging point, it was first ascertained, and through agency of the Pole star again, that

the north and south trenches were all but exactly parallel to the north-east and south-east sockets of the Pyramid's base; and then, that the grand diverging trench towards the east went off from them at an angle of 76° 18′ 38″; or the angle very nearly of the top of the Pyramid, according to Mr TAYLOR's hypothesis.

From the angle at the summit we can, of course, deduce trigonometrically the angle at the foot of the Pyramid; but we have that given also by these trenches in another and directer manner, viz., by the amount cut off the large angle by the small subsidiary trench; and if we take the mean of that and the former result, the angle comes out 51° 51′ 35″, nearly.

Now it may be said, that this close agreement with Mr TAYLOR's number is only an accident; but then *what* an accident! Tradition and subsequent history have indicated that the other Pyramids of Jeezeh were built in imitation of the Great Pyramid, and that their builders were well content with the success of their imitation; how close then to their grand exemplar did they come in this ethereal matter of angle?

The second Pyramid has an angle of 52° 50′; the third of 51° 0′; and the others are near upon 52° 12′: *i.e*, not one of them comes within a quarter of a degree.

Now I would not attempt to maintain against the architects, that these trenches were *not* used at the building of the Pyramid for mixing mortar in; nor would I argue against the Egyptologists, that they were *not* used for tombs, when the building was finished, and the mortar mixing over,—but I would only point out that these purposes in themselves cannot explain the angles at which the axes of the trenches are actually situated; and the cutting of them at these angles must have preceded the two subsequent utilitarian purposes the long cuts were eventually put to.

Hence opinion would seem to be driven to either one or other alternative; viz., if the Pyramid architects laid out these angles intentionally, they knew something of their scientific importance; but if they did not lay them out intentionally, and attained the precise angles without effort on their part, then, what some men call accident, others may prefer to look on as Providence overruling the fitful works of men for grander ultimate ends than they had any idea of at the time. But let us proceed further in our safe practical examination.

Proposition IV.

This proposition refers to the vertical angle of the long inclined passages in the interior of the Pyramid; they have been described by various travellers at anywhere between 25° and 27°, and even 30°; but Mr TAYLOR's theory extended says they should be at 26° 18′ 10″, and there are three different passages each to be measured. (See Plate XXVI.)

The first and second, viz., the entrance passage, and the first ascending passage, are indeed both small and of inferior workmanship, and were found by

my measures to be, one at 26° 27′, and the other at 26° 6′, or one too much and the other too little. But the grand gallery is a vastly superior passage, in height, breadth, length, and its whole architectural character, besides being a perfectly unique feature in the Great Pyramid over all the Pyramids of Egypt.

With the extremest anxiety therefore to be accurate, did I begin to measure the angle of the grand gallery by a clinometrical method. The clinometer itself, one of the most accurate instruments of the kind ever made in Europe, was one of the two separate instruments which my friend, Mr Andrew Coventry of this Society, voluntarily presented to me before going to Egypt, as an indication of his earnest desire to assist in having the Great Pyramid, if possible, better measured last winter in some of its crucial features, than it ever had been before.

In use, the fine part of the clinometer was fixed on a long and stout beam of mahogany duly prepared and furnished; and in that state the apparatus was made to step up the whole distance of one side of the grand gallery from north to south, and then to step down the other side from south to north, when the mean of all the observations in one day came out 26° 17′ 4″. Other observations were taken subsequently, and the mean of the whole was finally left at 26° 17′ 34″.

Proposition V.

The fifth proposition depends on a further development of the theory, and demands a latitude for the Great Pyramid close upon 30°.

The large alt-azimuth instrument was well adapted to this question, and from observations taken with it on the summit as well as at the foot of the Pyramid, the monument was found *not* to be in the required latitude, but at a distance of 21″ south of it.

The error is small enough, no doubt, and the Great Pyramid is moreover visibly nearer to the theoretical position, than any other Pyramid round about it: yet there are indications that the builders knew of the residual error, and tried to make it as small as possible. On no other hypothesis for instance can it be explained why, with the whole of the hill-top to choose upon for mere foundation, though not for latitude, the builders placed the Great Pyramid so very close to the northern side of the hill; even dangerously close to its actual northern cliff; for slickenside-scratches there prove large portions of the rocky edge already to have slided off, and there is a deep cleft preparing for another such rock-slip, which passes under the very north foot of the Pyramid. The builders knew it too, for they not only filled up the cleft with masonry, and covered it over; but they banked up a whole hill of rubbish against the north face of the cliff outside, as though to keep it up. And, hitherto, it has kept up; but meanwhile the Pyramid is realising much more nearly than most persons are aware of, the favourite quotation of many travellers as to its standing "on the utmost bound of the everlasting hills." (See Plate XXVII.)

Proposition VI.

When inquiring very closely into the ancient Pyramid's angles by means of *modern* observation, it becomes important, after eliminating errors of observation, dilapidation, and of workmen, to ascertain whether any slow geological changes of the earth's crust, accumulating during the 4000 years or more that the Pyramid has been standing, have introduced by this time any sensible alteration of the angles in the building as originally constructed.

Now without alluding to some indications of a shifting of the earth's crust over the place of the poles of rotation, a variety of our measures in the interior of the Pyramid do show a slight tilt or dip of the monument towards the south; and this is further testified to by the differences of the observed corner angles of the Pyramid outside, with the addition that there is a dip eastward also. The two directions are moreover the very ones in which all the component strata of the hill, and indeed all this part of the country do largely, though somewhat variously, dip, or have been so tipped by geological forces beginning from ages long anterior to the Pyramid, and now apparently continued to some extent within its history. The quantity of this post-pyramid tilt, in the Meridian direction, as given by the corner observations appears to be about 37″; it is therefore a rather small, and perhaps doubtful quantity; but yet we should note that if it be applied as a correction, with its proper sign to the previously observed angle in the grand gallery, it makes that important feature of the symbolization of this building come, within 1″, exactly the same as the theoretical quantity already given.

And now, Sir, I crave your pardon for having so exceedingly hurried over the numerous practical details of all these observations, and having told you little more than their final results,—but the truth is, they could not be completely set before you, except in a long series of discourses; and meanwhile, there are many other topics not less important which require to be touched on this evening.

Yet allow me, Sir, also to say, that at the stage whereto we have reached—I shall have altogether failed in my duty, if Members do not now begin to see that the builders of the Great Pyramid had a remarkable appreciation of certain definite angles, and realised them on an enormous scale, and with astonishing success; wherefore arises the very natural question,—What was all this labour for, and what object was sufficient to justify a cost so huge?

If the full explanation of these angles, and of certain other existing mechanical facts and features, is to accompany the true theory, then we must plainly wade through the mere burial hypothesis of the middle ages of the world, as wel as of the modern hierologists, and try what virtue there may be in that which is at once the oldest Eastern tradition, and the youngest Western theory, viz., the

metrological; implying in other words, that the Great Pyramid was primarily,—whatever it may have been made into, or used for subsequently, and which we need not, therefore, now inquire into further,—a monument devoted to *weights and measures;* not so much as a place of frequent reference for them, but one where the original standards were to be preserved for some thousands of years, safe from the vicissitudes of empires, and the decay of nations.

To this *theory*, however, we will show no other favour, than to test it on every hand with the most extraordinary severity; and, let it come out from such an ordeal brighter, if it can.

(A.) *Standards of Size.*

In the ancient Coptic language, and still in the memory of some of the people of Egypt, the name "Pyramid" is derived from *Pyr* division, and *met* ten, or a division into ten; while again, in actual fact, the Pyramid with its five corner stones, is considered by many as symbolical of five; wherefore, if a system of weights and measures be appropriately included in a Coptic Pyramidal building, we might expect to find the numbers *ten* and *five* very frequently made use of.

Again, if the system be a complete one, that leading department or *linear* measure, will of course be represented. Under such a belief, very many writers have joined in looking for the grand standard of length in one side of the base of the Great Pyramid. What that length was precisely, no man knew, even approximately, until the corner sockets were recently uncovered; and even now that they have all four been seen, the best measures vary between 9102 and 9168 inches, the mean of all being 9142 British inches. Accepting these numbers for the time, what does such a length mean as a standard of linear measure?

First, have rushed forward to answer, the hierologist scholars with the cubit of the nilometer in their hands, well preserved from the most remote ages, and they declare *a priori*, that 400 times that cubit, exact and even, was the measure of the side of the base of the Great Pyramid; but on measuring the cubit, 400 times its length is found equal only to 8280 inches.

Next, have come forward various celebrated geodesists, declaring that the side of the Great Pyramid was made exactly equal to $\frac{1}{500}$ of a degree of the meridian previously measured for the purpose, such degree being $\frac{1}{360}$ of a circle.

But they had no proof that in the Pyramid-building day the circle was divided into 360 degrees; and even if it had been, $\frac{1}{500}$ of such a degree is equal only to 8750 inches

Lastly came Mr TAYLOR, teaching us to look not to anypart of the surface of the earth, but to its internal axis of rotation, as the only fit reference for the highest class of linear measure, and to divide it decimally: that is, for *distance*-measuring to take $\frac{1}{10}$millionth of the *radius* of rotation for the standard; express-

ing that in units, whereof the peculiarly Pyramid number of five hundred millions measure the whole axis of rotation.

Such a small standard then possesses 5×5 or 25 of the units; which being longer than British inches by only ·001 of an inch, we may call Pyramid inches; while the whole 25 of them make up a length which is almost identically that of the ancient sacred cubit of the Israelites as determined by Sir Isaac Newton; and very notably different from that other cubit which, according to him, they used for ordinary purposes, and called the "profane cubit," because it was the same as that in vogue among the Egyptians, Phœnicians, and other Gentile nations. We shall allude, therefore, to a standard composed of 25 of these Pyramid inches, as the cubit of the Pyramid; and may have to note again and again the curious triple parallelism which prevails between the inner Pyramid, sacred Hebrew, and ancient Saxon measures.

But how is that 25 inch cubit to be identified with the 9142 inch base side of the Great Pyramid?

In this simple and suggestive manner;—there are in that base side as many lengths of that cubit as there are days in a year; *i.e.*, $365{\cdot}25 \times 25$, and reduced from Pyramid to British inches, the units in terms of which all our Pyramid measures are expressed, amount to 9140.

(B.) *Standards of Weight.*

If weight measure is to be anything more than accidental in its origin, it must be connected with the previously established linear standard, through the medium of capacity measures connected with the doctrine of specific gravity.

On this well known principle, several authors have decided on the granite coffer, a hollow, lidless, rectangular vessel, cut with great skill out of a huge mass of dark red granite (porphyry according to some), and carefully preserved in the secluded King's chamber near the centre of the Great Pyramid, being, in its hollow contents, the capacity standard, and in the weight of that content of water, the weight standard of the Great Pyramid. Foremost amongst these authorities is again the late JOHN TAYLOR, who has further shown that the coffer is alike the parent of the Hebrew chomer, and also of the old Saxon quarter, as capacity measures for corn, each of these being the $\frac{1}{4}$ part of the coffer.

This inference hinges entirely on what the measured contents of the coffer may be, and though the results given by some travellers are in Mr TAYLOR's favour, the statements of others are not a little contradictory. With eager zeal, therefore, I went to the coffer one morning armed with many measuring rods, and hoping to be able, in so small and simple a matter, to see immediately who was right and who was wrong,—when lo! there was an anomaly that *no one*, out of all the various authors, had ever noticed.

Here is a carefully constructed model of the coffer as it now stands, of $\frac{1}{10}$ the

linear size. Chipped along all the edges and grievously broken at one corner, as I was prepared to find it; but with also, a totally unexpected ledge cut inside the top and all across the western side, to a depth of 1·72 inches; and this ledge not only takes away near 4000 inches from the cubic capacity of the vessel, but enables all men to say—"so! this coffer, then, this lidless box of history, this "granite chest without a top, this porphyry vase of measure we have heard so "much about, is nothing but a sarcophagus after all:" for the ledge is so very similar to that by which the lids of sarcophagi are slided into their places.

The case was really most egregious in one way or another; and every student of Egyptian history, on first hearing of so unexpected a discovery, cannot fail to be beset according to his theoretical prepossessions, either with intoxicating triumph, or the confusion of dire defeat.

"Why were we not informed of all this by earlier travellers," some will exclaim! And others in their agony will turn again to the magnificent engravings of the so called immortal French national work on Egypt, and say, "Look at the "regular and equal sides of the coffer in these exquisite pictures; is it not *impos-* "*sible* that there could have been a ledge cut into them when their portraits were "taken at the end of last century?" But then, alas! who will be answerable for the perfect accuracy of even French academicians?

In short, we must investigate the matter *de novo*, and by measures of line and angle.

My first step, therefore, was to study acknowledged sarcophagi and their lids; and here is a model of the sarcophagus of the second Pyramid and its lid. They are both well preserved; and by an ingenious arrangement of the angles of the sliding grooves, combined with certain little fixing pins, they form a system which locks itself when the lid is pushed into its place.

Let us now make a similarly proportioned lid for a restored model of the great Pyramid coffer and its ledge, attending though to its peculiar angles; and then we find, after pushing that lid into its place, it has, and can have, no locking power whatever. Now there is a piece of clumsiness in contrivance, or inferiority in execution, which we should be careful how we charge on the architects of the Great Pyramid, where every other part is planned so much more skilfully than in any other Pyramid; and we may easily see, too, that the ledge is actually nothing more than a portion taken out of, and away from, an *originally* unledged and merely box-sided vessel.

Then if that be the case, we have nothing to do with the vessel's capacity in the ledged state, only with what it measured in its original unledged state; and then, did it or did it not coincide with one, precise, invariable theoretical quantity, depending on the cube of $\frac{1}{10}$millionth of the earth's axis of rotation or 50 inches, and the mean density or specific gravity of the earth as a whole, divided by ten?

This last important element is not known even to modern science quite so

accurately as it should be, but produces, with its best known determination in the above expression, close upon 71,250 inches.

Now, that is not a likely quantity for an Egyptian sarcophagus to measure inside, for all that I examined were very much less, many of them only half or at most $\frac{2}{3}$, even when treated as unledged vessels; but when the Pyramid coffer came to be measured, and with extreme care both to make the most of all original traces and to correct for small errors of figure, the result then came out 71,316 inches. So exactly, too, is the vessel constructed for purposes, or suitably with the requirements, of commensurability, that the capacity of the outside divided by two = 71,160; and the mean of both = 71,238. Hence it would appear to be the right vessel after all; and the parent, as to size, of both the sacred Hebrew, and ancient Saxon capacity measures. But it receives some further corroboration from the place in which it stands—the so-called King's chamber.

Over the doorway outside this room is an eminent symbol of five; and again, on entering the chamber, an attentive observer finds himself in the midst of a still grander masonic symbol of five; in that the granite walls are formed of *five* even courses (see Plate XXVIII.), running round and round the room at the same precise height, and in a manner quite unique in the general Pyramid masonry.* Each of these five courses, too, is of exactly the same thickness as every other, excepting only the lowest one, and that is five inches less than the rest. Not in reality, indeed, for it is an appearance produced to observation by the manner in which the granite flooring is introduced *within* the granite walls.

Still, why was it introduced in that manner, breaking in upon the admirable equality of all the other steps of this symbol—of five, pervading the whole chamber?

* As an illustration of the necessity of the present remeasurement, the following contradictory accounts by modern travellers, of the wall-courses of this room, the King's Chamber in the Great Pyramid, may be cited :—

George Sandys, A.D. 1610.—"Eight stones flagge the ends, and sixteen the sides."

Professor Greaves, A.D. 1639.—"From the top of it descending to the bottom, there are but "*six* ranges of stone, all of which, being respectively sized to an equal height, very gracefully in one "and the same altitude run round the room."

Lord Egmont, A.D. 1709.—"The walls were composed of *five* ranges of stone."

Dr Shaw, A.D. 1721.—"Height (of *five* equal stones) = 16 feet."

Dr Pococke, A.D. 1743.—"*Six* tiers of stones, of equal breadth, compose the sides."

M. Fourmont, A.D. 1755.—"The walls were composed of *six* equal ranges."

Dr Clark, A.D. 1801.—"There are only *six* ranges of stone from the floor to the roof."

Dr Richardson, A.D. 1817.—"Lined all round with broad flat stones of large red-grained "granite, smooth, highly polished, *each* stone ascending from the floor to the ceiling."

Lord Lindsay, A.D. 1838.—"A noble apartment, cased with enormous slabs of granite *twenty* "*feet high*."

W. R. Wilde, M.R.I.A., A.D. 1838.—"An oblong apartment, the sides of which are formed of "enormous blocks of granite reaching *from the floor to the ceiling*."

Mr E. W. Lane and Mrs Poole, A.D. 1843.—"Number of courses in walls of King's "Chamber, *six*."

Sir Robert Ainslie, in 1804, copied by J. Taylor in 1859.—An engraving, showing *six* courses between floor and ceiling.

This may have been one element connected with the reason; that lowest course of the room forms in fact a sort of larger coffer, or a tank containing within itself the smaller coffer; and the capacity of that course of the room, being computed carefully, subject to the very peculiar and hitherto unnoticed correction given to it by the original builders, is equal to *fifty* times the capacity of the coffer, or comes out actually in numbers so divided, 71,292.

There is even more testimony still, as to the distinguishing number 50, and proof which I had certainly never expected to obtain, until it showed itself on quite a different inquiry. The bulk of the mass of the Pyramid, as already mentioned, is composed of rectangular courses of masonry, rude but strong, and though excessively irregular in their consecutive heights, still every course preserves its own height admirably round and through the Pyramid, and keeps a good horizontal level. I had measured the individual heights of all the several courses with some accuracy, in going up and down the Pyramid, merely because they were the literal stepping-stones towards obtaining the whole height; and have only recently ascertained that the *fiftieth* course from the ground has a horizontal plane, which coincides with the floor on which the coffer stands in its tank of *fifty*, in its chamber of *five*; or, in other words, and looking to what went before, the coffer is not only the right vessel, but it is still standing in the right chamber; and all the substance of the Pyramid was built in deference to, and unison with that chamber and its internal symbolizations.

It only remains, therefore, now to state the neat, and, so to speak pyramidal form, in which a small standard of Pyramid weight may be most scientifically described, and in noble reference to universal weight and capacity measure; for if the whole coffer weight be divided by 50 times 50, yielding what may be called a pound-weight of the Pyramid, it is representable anywhere, with the utmost exactness, as *five cubic inches of the earth's mean density*.

(C.) *Standards of Heat.*

Of heat I shall merely attempt to say, on the present occasion, that the theoretical idea is, that the temperature of that remarkable chamber of *five* in the Pyramid, was intended to be a temperature of $\frac{1}{5}$; *i.e.*, $\frac{1}{5}$ the distance from freezing up towards boiling of water, amounting in Fahr. to 68°.

But the moment the measure is taken at the Pyramid, it is found to be about 74° or 75°. The present circumstances of the room, however, are entirely abnormal and in a way that should raise its temperature. Falling back therefore on the mean temperature of the air taken night and day for the first four months of the year at the foot of the hill, and also on the temperature of wells there, these are both found 64°·0 nearly; increasing which by several degrees to reduce the mean of these four months to the mean of the whole twelve, and deducting a smaller correction for elevation to the level of the Pyramid, we attain a tem-

perature for it under natural circumstances, which if not 68° exactly, is as close to it, as the mean temperature of any one year is usually found to the mean of a number.

(D.) *Standards of Angle.*

Measures of angle present themselves shortly at the Pyramid in the following manner:—several modern philosophers have already stated their beliefs elsewhere that the builders of the Pyramid must have been too barbarous and primitive to have any idea of angle, as angular measure; and that although the interior passages are set at certain angles, that arose only as a consequence of specified linear proportions being adopted in the building,—the proportion of two horizontal to one vertical being a very favourite instance and giving an angle of 26° 34′. Against this statement the answer seems to be, 1*st*, That every one of the inclined passages points to a sensibly smaller angle than 26° 34′. 2*d*, That the manner of showing the angles in the azimuth trenches, is incompatible with linear, and only adapted to angular, measure. And 3*d*, The angles of the sides of the Pyramid, as well as those of the passages and some other features too, are strongly indicative of angular measure having been highly appreciated in some of its crucial refinements. That such Pyramid angular measure too, if existing at all, was represented in the favourite Pyramid numbers, would seem to follow on the rule applied to obtain the dominant standards elsewhere; for if we assume a quadrant = 250°, and the circle 1000°, then the two dominant angles of the Pyramid, the 51° 51′ 14″ ($\frac{9}{360}$) of the sides, and the 26° 18′ 10″ ($\frac{9}{360}$) of the passages are representable by even numbers of the *Pyramid* degrees, to an accuracy of less than a tenth of one of those degrees; as thus, 144·0 ($\frac{9}{1000}$) and 73·0 ($\frac{9}{1000}$).

(E.) *Standards of Time.*

At first sight we might consider that measures of time could have no place in a pyramidally arranged building, because the utter incommensurability of the day and year prevent any satisfactory introduction there of fives and tens.

Yet time evidently *was* included in the idea of the Great Pyramid, when the linear standard, as we showed some time since, was expressed in terms of time. Moreover some persons may argue that though the day and year may be difficult to settle pyramidally,—the day and week are easy enough; for what is to prevent men having weeks of five days or ten days each! And in fact some of the hieroglyphic scholars maintain that the Egyptians of and about the Pyramid age actually did employ weeks of ten days each. May we expect then to find such weeks enshrined in the Great Pyramid?

Not necessarily, seeing that the several departments of measure hitherto recognised in the monument, have by no means proved to be those in use among the Egyptians, but rather to point to a different origin altogether. Let us there-

fore simply try to see what there is in the Pyramid, hoping only that the indications may be sure and unmistakable.

The grand gallery has long since been quoted as the part of the Pyramid, where time-measures may be expected to appear,—and men have also frequently remarked on the "seven overlappings" which run from end to end of the gallery, and form its chief architectural feature; but the most precise testimony expected by the theory was, that the whole height of the grand gallery might be found seven times that of a small passage; the height of such small passage being supposed to represent a unit-day.

Examination at the place soon showed that the small passages are not of invariable height. No objection need be taken in principle to that, for men must not come to this part of the Pyramid seeking standards of *linear* measure, these things being provided elsewhere with greater accuracy than would be possible here. We take the mean therefore of the vertical heights first of the passage entering the north end, and second, of that leaving the south end of the grand gallery, and find such quantity to be 48·4 inches.

Now, what is the vertical height of the grand gallery? This has been extremely variously estimated, and with great difficulty by different travellers; and to put me into a more favourable position than my predecessors was the object of the second instrument, with which the free and spontaneous liberality of my friend Mr COVENTRY supplied me, viz., the long measuring rod which you see stretched along both chimney-pieces. This being duly employed at many places in the length of the gallery, gave as a mean for the vertical height 339·5 inches, whose $\frac{1}{7}$th is 48·5 inches; *i.e.*, 48·4 is much rather the $\frac{1}{7}$th than the $\frac{1}{6}$th, $\frac{1}{8}$th or $\frac{1}{9}$th of the grand gallery.

This close approach then is the full amount of testimony that had been expected to be found, or had been asked for. But the building affords more.

Under the grand gallery, southward runs a small horizontal passage, from whose total length a part equal to $\frac{1}{7}$th of the whole is conspicuously cut off; and this passage leads into a chamber, the mean breadth of whose floor is equal to this $\frac{1}{7}$th of its entrance passage.

The object of this chamber, called without any reason the Queen's chamber, has been a serious puzzle to the learned.

Hierologists have considered it was intended for the burial of some one, but who was never brought to it; and architects have considered it was merely a space for storing, during the progress of the Pyramid's building, the large blocks of stone which were afterwards employed in filling up the inclined entrance passage from the inside.

But if constructed merely for such a purpose, would the whitest and fairest stone combined with the most exquisite workmanship in the whole Pyramid have been spent on the walls of this room? There is now a coating of salt over

most of the stone; but wherever the original surface or the joints can be met with, they are precisely as I have described; fair white stone, and joints conscientiously cemented yet microscopically fine.

This is a fact; so is it also that the room, so remarkably approached, has seven sides, on account of the peculiar double form of the ceiling, as shown in the diagram. (See Plate XXVIII.) These sides too are not very far from equal, especially when we supply, as we are bound to do, on the rough unfinished floor some fine lining blocks, similar to those of the walls.

But there is still something wanting to measured symmetry; and we notice in the east wall of the room, the large, well-wrought, deep-reaching niche which is without a parallel through the whole of the Great Pyramid. The mechanical effect of that niche on a computation of the bulk of the room, is plainly equivalent to the eastern wall being pushed outwards somewhat; not to the full depth evidently of the niche, but probably somewhere between twenty and thirty inches; I tried twenty-five in the computation and then found that, expressed in ten thousand square inches, six of the walls each measure accurately three, and the seventh measures five.

Now we had been previously led to look on this room as a masonried representation of the week of seven days; and here we have that realised with the addition, that six of them are ordinary days followed by, or founded on, one of greater importance; which is, in number, not only the definition precisely of the sacred Hebrew week of Genesis and Sinai, but is entirely peculiar to that one, and ancient arrangement of days. The full precision, however, of this result depends on the somewhat arbitrary employment of twenty-five inches of increased length to the room; something of the sort should be done on account of the great niche-space; but what authority does the room afford for that particular length?

Look round about the room now (Plate XXVIII.) if you please, and if there be any anomaly at all, other than the existence of the niche, it is, that so admirably wrought an architectural decoration is not in the centre of its containing wall.

Why it should not have been constructed in the centre, I have never heard the remotest guess; but measure the distance of its vertical axis from the same feature of the room, and you will find it just this twenty-five inches, or the sacred cubit, first of the Pyramid, subsequently of the Israelites, and now, by the light of modern science, shown to be no accidental length, but the one ten-millionth of the earth's radius of rotation.

Such then is the standard under which this remarkable arrangement of the *chamber of seven* was constructed; and, from the manner of its construction, at no other time than that of the original building of the Pyramid; sealed up too from that, or near that, time to all mankind, until the accident which was more than an accident, and revealed this part of the interior of the Pyramid to Caliph ALMAMOUN only a few hundred years ago.

What was the date then of the construction of this chamber of seven?

Why, of course it was the same as that of the building of the Great Pyramid; and if you ask when that was built, the answer is strange for the exactness and precision of some literary inquiries. Nearly fifty years ago the best writers fixed the date at 1800 B.C.; but within twenty years since, 2400 B.C. was considered nearer the mark; still more recently the German scholars who are so highly thought of at present in most of our universities, extended the time to 3200 B.C., then to 3700 B.C., and at last M. RENAN in France, has just announced that the epoch cannot be less than 4500 or 4700 B.C.

In the midst of all these contradictions then, what does the Pyramid say for itself? If it deals in time measures at all, it ought to have some capable of measuring large, as well as small intervals of time. In short, what of the astronomy of the Pyramid?

Astronomy has been tried already to settle the age of the Great Pyramid, by several eminent men; there was the happy identification for instance in 1838 by Sir JOHN HERSCHEL of the direction of the entrance passage with the once position of α Draconis, giving a date of about 2160 B.C., which agreed perfectly with the literary authorities of the time. But when these had grown in twenty years to 3400 B.C., then came MAHMOUD BEY, the Egyptian astronomer, with a reference of the star Sirius, the ancient Soth, or Sothis of the Siriadic land, to the southern side of the Pyramid in a manner that brought out a date also of 3400 B.C.; and then too it was found that Sir JOHN HERSCHEL's idea of α Draconis admitted of a second solution, which likewise gave 3400 B.C. nearly. But since then the literary dates have gone up so much higher as to throw all astronomy into discredit.

What then of the examination of the Pyramid last winter?

This shortly; 1*st*, The Great Pyramid's astronomy is not observing astronomy; the Pyramid was not intended to be used as an astronomical observatory; it symbolizes only.

2*d*, MAHMOUD BEY's idea of Sirius has nothing positive to connect it with the Pyramid, and has three out of four possible features absolutely against it.

3*d*, Sir JOHN HERSCHEL's idea of the entrance passage and α Draconis is very good so far as it goes, but it was not conducted far enough to reach a positive conclusion.

As I may gratefully acknowledge to that eminent philosopher, he taught me years ago the importance in scientific investigation of attending excessively to all anomalies in results. And on that principle I was much troubled at the Pyramid to see, that if α Draconis had been made such important use of as the ancient Polar star, only one of its two daily meridian passages had been marked; and that one, the lower and less important.

Why such an anomaly? Convinced by much experience at the Pyramid that there is hardly anything there without a reason—I concluded,—"because, when

that star was crossing the meridian *below* the Pole, a more important star was crossing *above* the Pole; and it is the manner of the Pyramid not to wear its most vital truths in prominent outside positions."

Out of that consideration seems to have come the full explanation, of which the lateness of the evening prevents my doing more than briefly noticing the end, —as thus—

The more important star or star-group was, the Pleiades.

The grand gallery with its seven overlappings and peculiar angular position, is commemorative, amongst other things, of the proverbial seven stars.

The Polar star, α Draconis, was first employed to regulate the meridian position of the Pyramid; and then, the Pleiades, at that date a nearly equatorial star, was observed when on the meridian and at a high altitude, to obtain an accurate instant of time.

The epoch, was the *last* occasion when α Draconis was $3^{\circ}\,42'$ from the Pole or in 2170 B.C; and then, not only were the Pleiades opposite to α Draconis almost exactly in Right Ascension, or crossing the Meridian above the Pole, when α Draconis was crossing below the Pole; but they, the Pleiades, were in a most peculiar cosmical position, well worthy of being monumentally commemorated; for they were actually at the commencing point of all Right Ascension, or at the very beginning of running that grand round of stellar chronological mensuration which takes 25,868 years to return into itself again; and has been termed elsewhere, for reasons derived from far other studies than anything hitherto connected with the Great Pyramid, *the Great year of the Pleiades.*

If, moreover, we would desire to learn whether the founders of the Pyramid really had in that early age of the world a knowledge of the entire duration of so grand a cycle of time, we may seek the answer in the base of the entire monument; where the sum of the two diagonals, whose equality best proves our first proposition of all, or the squareness of the base, amounts, at the rate of an inch for a year, to 25,836 years.

Perhaps now some attempt to indicate who the men were who planned, or under what guidance it was that they were enabled to plan in the year 2170 B.C. such a monument as the Great Pyramid, should follow; but I rather imagine the inquiry ought from this point to pass into other and stronger hands than mine; and I will therefore this evening, with your leave, only make one farewell remark,—it is to request special attention to the radical difference between the known vulgar measures of Egypt, such as they have been through all periods of her history, either Ancient or Modern,—and Great Pyramid measures, as illustrated in that building's carefully deposited, but long concealed, metrological arrangements. Take for example the two terminations of either system.

At one end, as the linear standard of Egypt in all time past and present, you

have the cubit of the Nilometer; an accidental length of trifling character, and incommensurable evenly with anything noble under the sun; but for the linear standard of the Great Pyramid, you have no less precise or suggestive a quantity than one ten-millionth of the earth's radius of rotation.

At the other end,—in the star Sirius, Soth or Sothis, the Great dog-star, which the Egyptians voluntarily, even obstinately selected out of all the host of heaven to identify the history of their country with,—modern astronomy shows, that what with its very large amount of proper motion, historical change of that proper motion, and orbital movements round some dark body unknown, they could not have picked out for long chronological referring purposes a more inaccurate or unsatisfactory star.

But in the star, or star-group of reference chosen for the Great Pyramid, viz., the Pleiades, though not the brightest and most glaring in the sky, yet is it a group (as particularly shown by the extensive researches of Mr R. G. Haliburton of Halifax, Nova Scotia),* connected of old by all primeval nations and primitive tribes of men with "sweet influences," and with deeply wise traditions too, dating from as early and mysterious an origin, as human language itself; while by the latest advances of modern physical astronomy this favoured Pleiades group is supposed to contain the orb, which is the central orb, of all the sidereal globes.

APPENDIX I.

The numerical observations so very shortly alluded to in the foregoing Address, occupy in MS., as prepared for intended future publication, rather more than 300 pages, and are distributed in subject, thus:—

PART A.—*Linear Measures.*

	Pages.
Introduction,	1 to 5
Entrance Passage of Great Pyramid,	6 39
First Ascending Passage,	40 51
Horizontal Passage and Queen's Chamber,	52 65
Grand Gallery,	66 94
Antechamber,	95 106
King's Chamber,	107 120
The Coffer,	121 131
Azimuth Trenches,	132 135
Height and Breadth of Base of Great Pyramid,	136 145

* "New Materials for the History of Man, derived from a Comparison of the Calendars and Festivals of Nations," by R. G. Haliburton, F.S.A., Halifax, Nova Scotia. 1863. Printed privately.

PART B.—*Angular Measures, Geometrical.*

	Pages.
Introduction,	146 to 150
Entrance Passage of Great Pyramid,	151 155
First Ascending Passage,	156 157
Horizontal Passage to Queen's Chamber,	158
Grand Gallery,	159 166
Walls of King's Chamber,	167 168
Ventilating Channels,	169
Exterior Faces of Great Pyramid,	170
Casing-stone Fragments,	171 173
Corner Angles of Great Pyramid,	174 179

PART C.—*Angular Measures, Astronomical.*

Time Observations,	180 182
Latitude Observations,	183 186
Round of Azimuths,	187
Azimuth Trenches,	188 190
Azimuth of Pyramid Entrance Passage,	191 193
Azimuth of Pyramid Corner Sockets,	194 196

PART D.—*Heat Measures.*

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Well Temperatures near Cairo,	200 201
Well Temperatures near the Pyramids,	202 203
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Meteorological Journal at East Tombs, from January to April 1865,	207 258
Cycle of a Day,	259 260
Meteorology of the Months,	261 264
Mean Daily Temperature,	265 267
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PART E.—*Miscellaneous and Communicated Measures.*

Measures of the Second Pyramid,	272 274
Photographs, description of, 166 single, and 57 double,	275 283
List of Specimens brought home,	284 284
Analysis of Specimens by William Wallace, Esq., Ph.D., Glasgow,	285 288
Pyramid Measures by Mr Ayrton,	289 291
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" " Col. Howard Vyse and Mr Perring,	309 315
" " Mr E. W. Lane,	316 319
Professor Greaves's Standard of Linear Measure,	320 322

APPENDIX II.

SPECIMENS FROM GREAT PYRAMID REGION, PRESENTED TO THE ROYAL SOCIETY, EDINBURGH, AND TO BE SEEN IN THEIR MUSEUM.

A.—*Examples of the Natural Rock.*

1. Large specimen of nummulitic rock from the neighbourhood of the Great Pyramid, and abounding in both large and small nummulites.
2. Smaller do do.
3. Do. do. do.
4. Hand specimen of rock, almost entirely a congeries of small nummulites.
5, 6, and 7. Portions of the lime-stone rock, with fossils, from the neighbourhood of the Second Pyramid.
8. Loose nummulites, large and small.
9. Echinus and other separate fossils of the nummulitic rock.
10. Sulphate of lime, found near the Third Pyramid.
11. Four specimens of fossil wood found on the desert surface West of the Pyramids: one of them recently sawn in Edinburgh.
12. Jasper and quartz pebbles, large and small, found similarly on the desert hill surface.
13. Two portions of an ancient rock-matrix holding said pebbles.
14. Specimens from a hill about three miles south of the Great Pyramid, all of more recent formation than the nummulite, and consisting of large echini out of "green-sand"(?), and numbers of well-preserved cardium shells, casts of volutes, and portions of rock made up almost exclusively of organic remains.
15. Drift-sand of the desert, from near the Sphinx.

B.—*Examples of Imported Materials.*

These were picked up on the open ground of the Pyramid hill, in so far like naturally placed specimens, but were undoubtedly brought to the Pyramid region by man, and for building purposes; in testimony whereof, portions of one or more *worked* surfaces are usually to be seen on every fragment; and if such specimens are now mixed up with the soil of the hill, and only to be obtained by digging,—that indicates the great length of time which must have elapsed since the monuments, which these stones once helped to form, were broken to pieces.

1. Large lump of dark red granite, similar to the material of the coffer.
2. Smaller lump of light red granite.
3. Smaller piece of light-red granite, one side polished.
4. Three varieties of coarse black basalt, each of them with worked surfaces.
5. Remarkably fine-grained basalt, excessively hard, and having a portion of a rectangular edge exquisitely worked, and left rather higher than the more central part of the surface, as if to insure the stone standing firmly by resting on its circumference when introduced into some construction.
6. Fragment of diorite, from the ancient rubbish-heap on the north flank of the Great Pyramid hill.
7. Three specimens of arragonite from the neighbourhood of Shafre's tomb and the temple on the east of the Second Pyramid.

C.—*Casing-Stone Fragments of Great Pyramid.*

These were picked up amongst the innumerable fragments of stone composing the small hills of modern rubbish which lean against the middle of the lower

part of each side of the Great Pyramid. All the fragments nearly of those hills seem, from their composition, to have belonged to the casing-stones; but only a few are *provable*, by chancing to have a portion of the bevilled surface and an adjoining portion of one of the horizontal surfaces, or an arrangement capable of showing the angle of the ancient slope.

The sixteen specimens presented to the Royal Society, Edinburgh, are of this latter class, and are arranged as follows:—

Three specimens showing the upper angle of the casing-stone or 128° 9′, are inserted along the similar edge of a wooden model of a casing-stone 20 inches long and 7 inches high, and with the angle made true according to the theory.

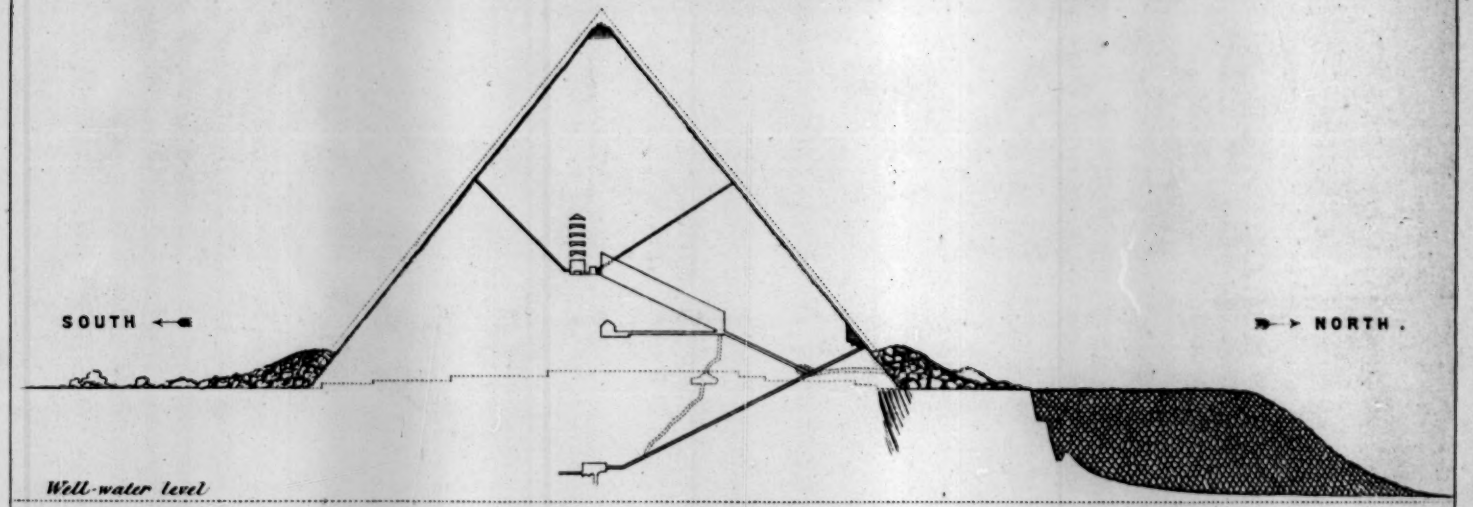
One large specimen of the 128° 9′ angle, and another of the 51° 51′ angle standing upon it, are nserted in a model of a casing-stone 24 inches long and 5 inches high.

And eight specimens of the 128° 9′ angle, with three of the 51° 51′ angle are arranged partly in a horizontal section, and partly at the foot of a model of the whole Pyramid about 25 inches long in one side of its base, and with the angle of the sides true according to John Taylor's theory of them.

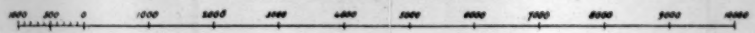
Finally one small fragment of a casing-stone recently cut and polished, to show the nature of the material.

VERTICAL SECTION OF GREAT-PYRAMID OF JEEZEH,

IN THE PLANE OF THE PASSAGES.

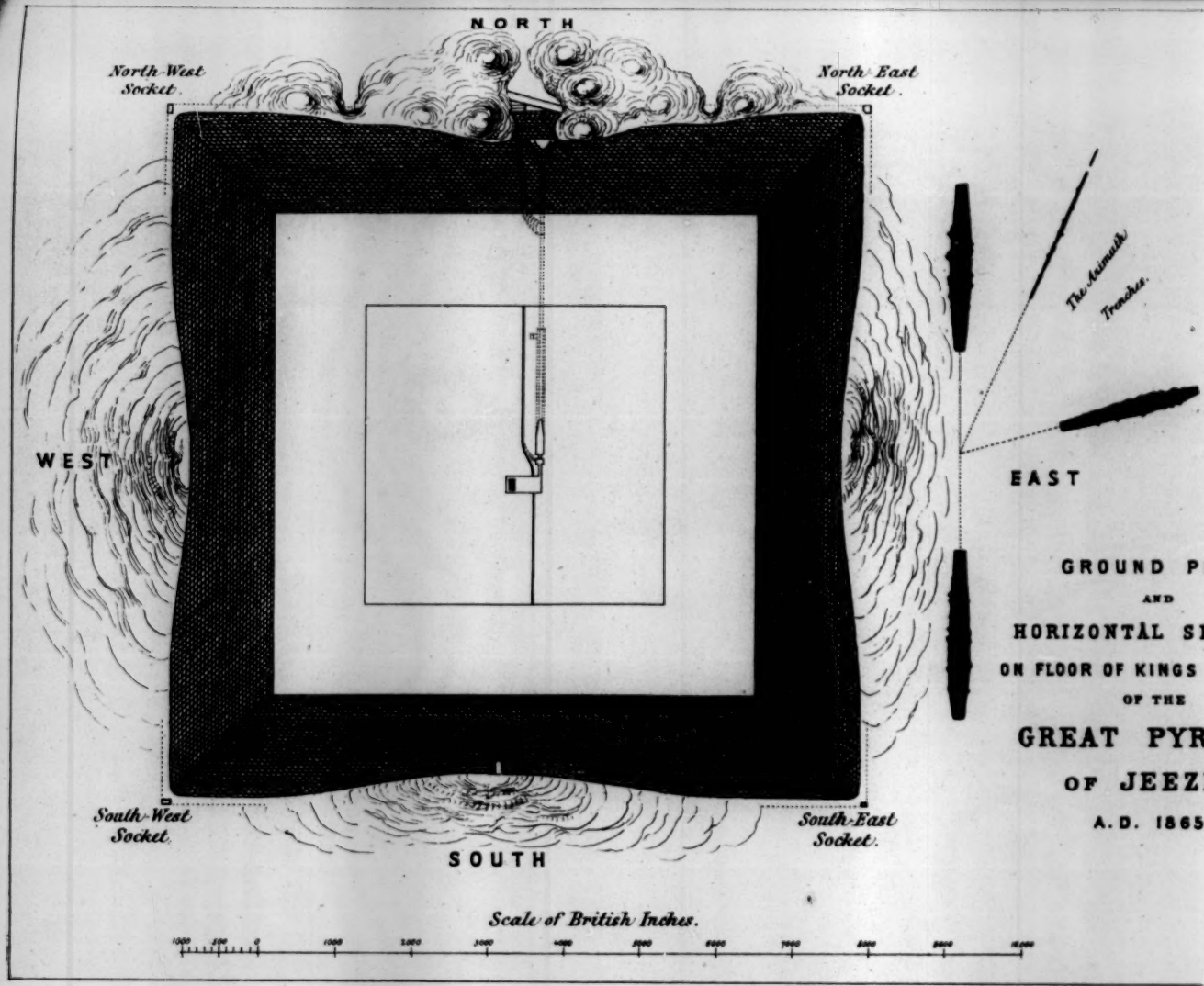


Scale of British Inches.



W.H. Mc Farlane, Lith.r Edin.r

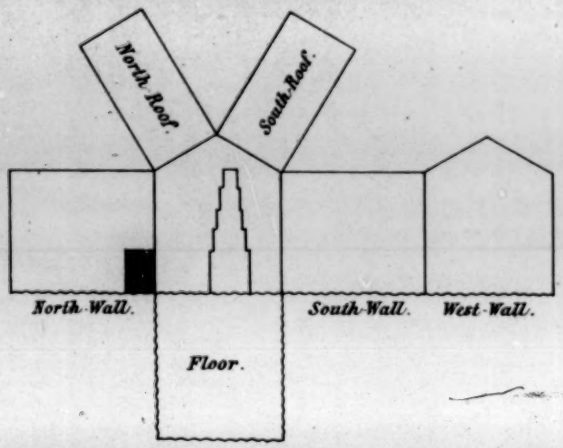
NORTH



GROUND PLAN AND HORIZONTAL SECTION ON FLOOR OF KINGS CHAMBER OF THE GREAT PYRAMID OF JEEZEH, A.D. 1865.

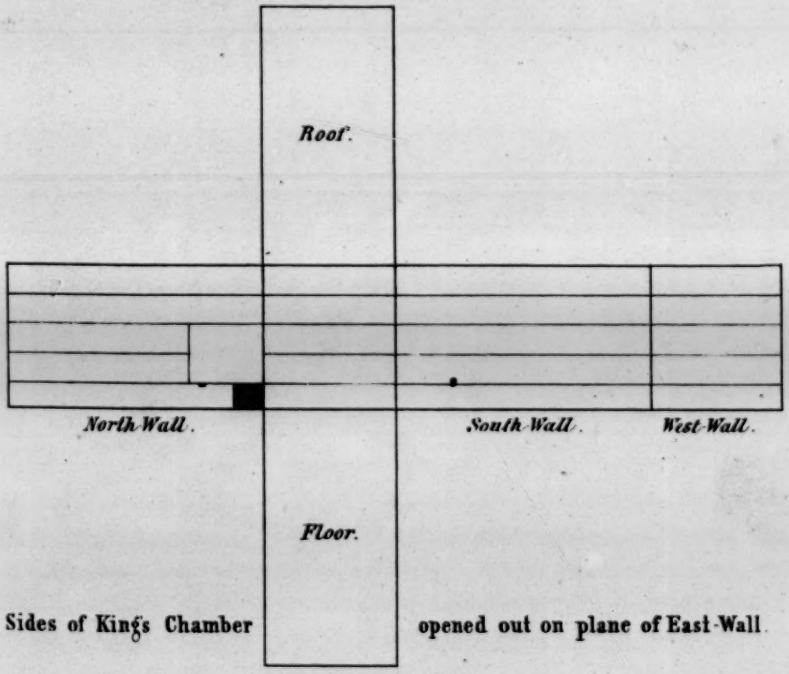
W. M.c Farlane, Lith.r Edin.r

THE CHAMBER OF SEVEN.



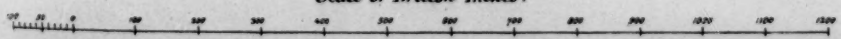
Sides of Queen's Chamber opened out on plane of East-Wall.

THE CHAMBER OF FIVE.



Sides of King's Chamber opened out on plane of East-Wall.

Scale of British Inches.



W.H. M.c Farlane, Lith.r Edin.r

XXX.—*Observations on New Lichens and Fungi collected in Otago, New Zealand.*

By W. Lauder Lindsay, M.D., F.L.S., Honorary Fellow of the Philosophical Institute of Canterbury, New Zealand. (Plates XXIX., XXX.)

(Read 2d January 1866.)

INTRODUCTION.

In 1861, in a part of the province of Otago, New Zealand, not previously botanically explored, I made, among other botanical collections,* one of Lichens and Fungi. The number of *new species* and varieties proved to be considerable, amounting to about 20 per cent. of the whole *lichens*, and 40 per cent. of the whole *fungi*, collected. Since my return home, I have submitted (with a view specially to the study of *the minute anatomy of the reproductive organs and their contents*) the new species (and varieties) in question—some of them repeatedly—to microscopical examination: the results whereof are contained in the notes which follow.

I hold that he only is fully competent to determine and describe species from *new countries*, who, in addition to the requisite analytical and descriptive power, has, on the one hand, constant access to, and an intimate knowledge of, the now overwhelming and ever-increasing mass of Botanical Literature in all the principal European languages; and, on the other, equally habitual access to Herbaria which contain the largest collections of specimens from all parts of the world, such, for instance, as those of Kew or Paris. By no other means does it appear possible now-a-days accurately to ascertain or *distinguish what is new from what is already known in the plant-world*. This virtually restricts systematic and descriptive botany to the Naturalists of London or Paris, or of similar centres of botanical knowledge; and as virtually excludes Provincial Botanists, who are isolated from the sources of the necessary fundamental information. It were easy for a collector or observer in a new field to name and describe, what to himself, according to his limited opportunities for judging, appears to be new. But if he do so, however otherwise qualified, without that knowledge, which can, generally speaking, only be acquired in the Botanical Libraries, and from the Herbaria, of the largest European cities, he cannot fail to add to the confusion of synonyms, and impede the true progress of botanical discovery and science, by

* *Vide* "Contributions to the Flora of Otago, New Zealand:" Transactions of Botanical Society of Edinburgh, vol. viii. p. 250: and "List of Lichens collected in Otago, New Zealand," *ibid.* p. 349.

publishing as new, and under new names, species, which a wider experience speedily proves to be identical with, or mere forms of, other plants already known as natives of other parts of the world. Collectors are, as a body and as a rule, naturally desirous of naming and describing their own collections; and, *in certain respects*, no other Botanists *can* be so well qualified to do so. Nor is it always possible to secure the co-operation of those overworked, eminent authorities, who have the largest knowledge of the special departments of botanical science which they respectively cultivate and adorn.

Holding such views, and in the absence, on my own part, of the necessary qualifications, advantages, or opportunities, I have gladly availed myself, *in the determination of species* (and to a certain extent also, in their description), of the valued assistance of my friends Dr NYLANDER of Paris (for Lichens), and FRED. CURREY, F.R.S., of London (for Fungi),—the one, the most eminent living authority in systematic and descriptive Lichenology; the other, one of our most accomplished British Fungologists.*

In reference to the following enumeration of Otago *Lichens*,—with one or two exceptions,—the *names* assigned are those of Dr NYLANDER,† who writes as follows regarding the Lichen collection:—

"Les votres sont d'un grande valeur pour la Flore Antarctique, surtout à cause des saxicoles et espèces d'un ordre inférieur qu'elle renferment et qui avant étaient trop imparfaitement représentés parmi les matériaux rapportés de ce bout du monde.‡ . . . Certainement les espèces . . . et les variétés sont *toutes nouvelles pour la Science.* La Flore de la Nouvelle Zélande a par vos découvertes fait des acquisitions importants dans le domaine lichénographique."§

In regard to the *Fungi*, in several cases I am indebted to Mr CURREY, not only for names, but also for specific diagnoses and notes on structure or affinities. In a few other cases (of fungi or fungo-lichenes), where complete materials do not exist in my collection for full description, the plants not being in a perfect state as to fruit or otherwise, I have assigned names with much diffidence, but not without due deliberation, in the belief that the subsequent researches (to which the names and notes now given may perhaps lead) of Local Botanists, who

* I use the term *Fungology* in preference to *Mycology* (referring to that department of botanical science which treats of *Fungi*), because, though less euphonious or elegant, it is also less open to misunderstanding; the term *Mycology* being equally applicable and applied to that department of *anatomical* science which treats of the *muscular* system in man and animals. I am borne out, in the preference of the term *Fungology*, by the recent and high authority of BERKELEY ("Outlines of British Fungology," 1860, p. 2).

† Since my "Observations" were committed to the printer, a paper by Dr NYLANDER, entitled "Lichenes Novæ Zelandiæ, quos ibi legit anno 1861 Dr LAUDER LINDSAY," has been published in the Journal of the Linnean Society: Botany, vol. ix. p. 244, which contains the specific diagnoses of the majority of the Lichens referred to in the following and aforesaid "Observations." Fortunately the paper has been issued in time to enable me to insert references thereto at their proper places in the present text.

‡ Letter, dated August 3, 1864.

§ Letter, dated August 22, 1865.

may have at command, for investigation, ample series of *living specimens*, in all their forms or conditions of growth, will prove the plants in question—what I here presume them to be—in reality new species.

I. LICHENES.—(PLATE XXIX.)

1. *Abrothallus Curreyi*, nov. sp. (figs. 1 to 5.)

Parasitic on the thallus of *Parmelia perforata*, Ach., (which is copiously covered with apothecia and spermogones): on the trunks and branches of dead trees,* Greenisland Bush.

In characters, this species is intermediate between *A. Smithii*, Tul., and *A. oxysporus*, Tul.† These species, when they occur (as they most frequently do) on the thallus of *Parmelia saxatilis*, Ach., are almost invariably found occupying special growths from, or anamorphoses of, its thallus. But *A. Curreyi* occurs directly on the ordinary thallus of *P. perforata* (fig. 1, *a b*), towards its periphery, in the position usually occupied by the spermogones of the *Parmelia* (*c*). In this respect it resembles other species of *Abrothallus*, which are parasitic on the thallus of other species of *Parmelia*, and on species of *Platysma* and *Stictina*.

The apothecia of *A. Curreyi* are less prominent and tuberculiform, and smaller than those of *A. Smithii;* more convex and protuberant than the discoid, flattened, sub-immersed ones of *A. oxysporus*. In *A. Curreyi*, the apothecia are typically minute, black, convex, and immarginate; partly immersed in the thallus, in whose superficial tissues they have been originally developed (figs. 1 *b*, 2 *a*). They vary, however, considerably in form and size, having a tendency on the one hand to become tuberculiform, and on the other, discoid. In the young and old states they are apt to be confounded with the *spermogones* of *P. perforata*, which are generally more or less abundant on adjoining lobes of the thallus. In the young state, the apothecia of *A. Curreyi* appear as very minute papillæ; in the old, when the tuberculiform hymenium has fallen away, it frequently leaves a black, stellate-fissured scar, resembling that characteristic of old emptied spermogones of the *Parmelia*. I have elsewhere‡ described the characters of these *spermogones* of the *Parmelia*, which are easily distinguishable from the apothecia of the *Abrothallus* on microscopical examination, though sometimes not otherwise. In my Otago specimens of *P. perforata*, I find its spermogones (figs. 1 *c*, 3) though generally sub-marginal, punctiform, and immersed, occasionally occupying also central positions on the

* Especially "Goai" (*Sophora tetraptera*, Aiton). *P. perforata* is equally abundant sometimes also on *living* trees in Saddlehill Bush, and other remnants of the primitive forest.

† "Monograph of the genus *Abrothallus*;" with two coloured plates.—*Quart. Journal of Microscopical Science*. January 1857.

‡ "Memoir on the Spermogones and Pycnides of the Higher Lichens."—*Trans. Royal Society Edinburgh*, vol. xxii. p. 211 (Plate II. figs. 4, 5).

thallus; large, prominent, and sub-papillate; seated on, or immersed in, minute thalline wartlets or elevations. They become, moreover, with age occasionally confluent and difform, frequently irregularly stellate or radiate (fig. 3 *b*). Generally speaking, corticolous forms of *P. perforata* are abundantly, while saxicolous ones in Otago are sparingly, spermogoniferous. In the former, spermogones sometimes abound to such an extent as to give the thallus, to the naked eye, a black-punctate character.

The constituents of the hymenium of *A. Curreyi* (fig. 4 *a d*), are somewhat indistinct, from their state of close aggregation. The tips of the paraphyses are dark-brown (*b*), very granular, and agglutinated; and they are covered by a colourless epithecial membrane (*a*). The hypothecial tissue is also very granular and dark (*d*). The *thecæ* (*c*) are of the typical form, ·0012″ long, and ·0006″ broad,* containing eight spores arranged in one or two rows. In the young state, and while crowded in the thecæ, these spores are generally sub-angular or otherwise difform from mutual pressure (*c*). The thecal lichenine gives a beautiful blue reaction with iodine; in this respect resembling *A. oxysporus*. The *spores* (fig. 5) are simple, colourless, sometimes showing a double contour, ·0003″ long, and ·00025″ broad; broadly ellipsoid or sub-oblong; sometimes slightly curved like those of the genus *Ramalina;* and also, like them, sometimes exhibiting a tendency to central division into two loculi (*a*), with occasionally a slight constriction opposite the septum. The spores thus resemble those of *A. oxysporus*, rather than those of *A. Smithii*, which are brown, solæform, and 1-septate. The tendency, however, to division and constriction is an approach to the characters of the latter. They are always much smaller, broader, more rounded at the ends, or more oblong, than those of *A. oxysporus*. With this species I have associated the name of my friend, the eminent Fungologist, Fred. Currey, F.R.S.

2. *A. oxysporus*, Tul. (fig. 6),

also occurs in Otago, apparently identical in its characters with its Scotch prototype.† I found it parasitic on the larger-lobed forms of *Parmelia conspersa*, Ach., which grow plentifully on basalt, in the gullies or glens of the Greenisland hills (*e.g.*, near Greenisland church). The apothecia are typically flattish or discoid; in the young state, however, they are frequently tuberculiform or sub-papillæform; and under moisture, in the mature condition, they swell so as to become sub-convex, and to assume somewhat the characters of those of *A. Smithii* and *A. Curreyi*. In the old state, generally from the falling away of the hymenium, they leave a black urceola, which may become irregular in its outline, or stellate-

* The microscopical analyses were made with a Nachet's microscope: objective ⅛″, ocular, No. 3—magnifying 425 diam.-linear; and the measurements here given are in decimal fractions of the English inch.

† "Monograph of Abrothallus," p. 80; "Memoir on Spermogones," p. 232–3.

fissured. As in *A. Curreyi*, the constituents of the hymenium are indistinct and closely united. The *paraphyses* contain much brown colouring matter about their tips, which are intimately agglutinated. The hymenial lichenine gives a blue reaction with iodine. The *spores* (fig. 6) are narrowly ellipsoid, almost fusiform; simple; sometimes with a double contour (*b*); colourless; ·00075″ long, and ·00025″ broad.

The genus *Abrothallus* (which is properly to be considered only a group of lower, parasitic, athalline *Lecideæ*), and the two species above recorded, are new to the New Zealand Flora.

From their minute size and inconspicuous character, the plants composing the genus in question are apt to be overlooked by all but the practised Lichenologist. From what I have myself seen, I have no reason to suppose them rarer in New Zealand than in Britain; and I have therefore to recommend their being carefully looked for by local Botanists on the thallus of the higher or foliaceous Lichens, especially in the genera *Parmelia* and *Stictina*.

3. *Melanospora Otagensis*, nov. sp.

(Lindsay "On a New *Melanospora* from Otago, N.Z.," Trans. Bot. Soc. Edin., vol. viii. p. 426, Plate V. figs. 7–12.)

Thallus sub-determinate, tartareous, thick, of cretaceous texture and chalk-white colour, sub-farinose, smoothish, sub-areolate. *Apothecia* vary in form from lirellæform (Opegraphoid) to angulose-patellæform (Lecidine): most usually they are short, sub-oblong, broadish pseudo-lirellæ, generally straight, black, simple, solitary and scattered, sub-sessile, base only sub-immersed. *Epithecium* rimæform or exposed, flat or concave; margin distinct, thickish, generally entire, sometimes more or less involute on the disk. *Spores* abundant and distinct, brown, 1-septate; about ·0006″ long, and ·0003″ broad; oval-oblong, constricted or not at the septum, sometimes figure-8 shaped or solæform.

Habitat on columnar basalt, Greenisland Bluff; associated with a sterile condition of *Pertusaria velata*, Turn. This species (which has been described from an imperfect specimen—the only one in my herbarium) appears closely allied to the British *M. cerebrina*, DC. (Mudd, "Manual," 226, E. Bot., Pl. 2632, fig. 1), so far as I can judge from figures and descriptions only. The family or tribe to which the genus *Melanospora* (Mudd) belongs, viz., the *Xylographidei*, Nyl., as well as the genus itself, and *M. Otagensis*, are alike *new to the New Zealand Flora*.*

4. *Lecidea Otagensis*, Nyl., Lich. N.Z., 255 (figs. 7, 8).

On stockyard fences of "Goai" timber; in the Bush, ravines of the Chain Hills, Greenisland: associated with *Arthonia excedens*, Nyl.

* *Vide* "List of Otago Lichens," pp. 356–8.

The apothecia somewhat resemble externally those of *L. grossa*, Pers., and *L. pulverea*, Borr. They are sometimes angular, or sub-lirellæform; sometimes sub-pedicellate. The hymenial gelatine and the thecæ become beautifully blue under iodine (fig. 7 *c*). Both hymenium and thecæ also contain large quantities of oil globules (*b*). The *thecæ* (*c*) are somewhat small; ·0015″ long, and ·00045″ broad; 8-spored, and of the ordinary form. The *paraphyses* are indistinct, and the dark-brown clavate heads are closely agglutinated (*a*). The *spores* (fig. 8) are ·0012″ long, and ·00001″ broad; acicular or very narrowly fusiform; colourless; generally slightly curved; poly-septate (frequently 3 to 5 septa); like the majority of lichen-spores, granular in the old and young states (*a*), with no distinction of loculi or septa.

5. *L. flavido-atra*, Nyl., Lich. N.Z., 257 (fig. 9).

On stockyard palings of "Goai," Martin's Bush, Chain Hills.

Externally it differs from *L. grossa*, Pers., *L. marginiflexa*, Tayl., and other *Lecideæ*, only by the colour of its thallus—a lemon yellow.

The *paraphyses* are indistinctly seen, but are sub-discrete, delicate, filiform, sub-hyaline, colourless even at their tips, which are not knobbed or clavate. The *thecæ* are large and distinct; 8-spored; ·0036″ long, and ·0015″ broad; giving a beautiful blue with iodine. The *spores* (fig. 9) are broadly ellipsoid; 1-septate; colourless; ·0009″ to ·0012″ long, and ·0006″ broad. In the young state (*a*) they are polari-bilocular, and save as to colour resemble those of *Physcia pulverulenta*, Fr. In the young state (*a*) also, the septum is generally wanting, and the loculi have a pale lemon-yellow tint.

6. *L. melanotropa*, Nyl., Lich. N.Z., 255 (fig. 10).

On trees and shrubs, Stoneyhill Bush; and on the bark of dead trees, Saddle-hill Bush; associated with *Arthonia excedens*, Nyl., and *Collema leucocarpum*, Tayl.

The apothecia in the young state are sometimes waxy or corneous, of a glaucous or olive hue, becoming, however, with age pitch-black, and then resembling those of *L. grossa*, Pers.

The constituents of the hymenium are most indistinct, and the spores (fig. 10) are with difficulty seen. The latter are globose or sub-globose; 1-septate, colourless, about ·0003″ in diameter. The hymenium and thecæ give a blue reaction with iodine.

7. *L. amphitropa*, Nyl., Lich. N.Z., 256 (fig. 11).

On rocks and the ground, Woodburn Ravine, Saddlehill.

The plant consists of a patch of white thallus, with a very few straggling black apothecia, resembling in general aspect our *L. epigæa*, Schær., or *L. Hookeri*, Schær.

The constituents of the hymenium are indistinct and closely aggregated. The

thecæ are smallish, but give a distinct deep blue with iodine. The *spores* (fig. 11) are fusiform, colourless, 3-septate, ·0009″ long, and ·00015″ broad.

8. *L. leucothalamia*, Nyl., Lich. N.Z., 255.

On the bark of dead trees, Saddlehill Bush.

Though the disk of the apothecium is generally whitish, its colour is variable, being sometimes glaucous or brownish, with a corneous aspect. It resembles somewhat *L. melanotropa*, Nyl., and *L. pulrerea*, Borr., from which the spores, however, at once distinguish it. A similar pallor of disk occasionally occurs in *L. marginiflexa*, Tayl., and other *Lecideæ*, whose apothecia are typically and usually pitch-black. The constituents of the hymenium are very indistinct and closely aggregated. The hymenial lichenine becomes blue with iodine. Both paraphyses and thecæ are shortish; I saw neither satisfactorily; nor did I see any spores.

Var. *melachroa*, Nyl., which occurs in the same locality, is simply a form with black apothecia, which then resemble those of *L. marginiflexa*, Tayl., *L. grossa*, Pers., and many other *Lecideæ*, with typically black apothecia.

9. *L. allotropa*, Nyl., Lich. N.Z., 254.

On Mica slate, Glen Martin, Chain Hill Range.

There was no result of microscopical examination worthy of record.

10. *L. coarctata*, Ach.; var. *exposita*, Nyl., Lich. N.Z., 254 (fig. 12).

On tertiary grits and conglomerates, base of Saddlehill.

The apothecia are mostly convex, resembling some forms of *L. parasema*, Ach. Sometimes they are sub-difform, or irregular in outline. At other times they exhibit remains of a coarctate or urceolate character, and they then resemble—as does the thallus—some forms of *Lecanora cinerea*, L.

The hymenium gives a very faint blue with iodine. The *paraphyses* are very indistinct and closely aggregated; they are obscured, especially about their tips, by much granular matter of a deep reddish-yellow colour. The *thecæ* approach in size and other characters those of *Urceolaria* and *Pertusaria*; they are ·0030″ to ·0036″ long, and ·0006″ to ·0009″ broad. The *spores* (fig. 12) are simple, colourless, ellipsoid-oblong, with double contour; frequently ·0006″ long, and ·00045″ broad.

11. *L. trachona*, Nyl.; var. *marginatula*, Nyl., Lich. N.Z., 254.

On columnar basalt, Greenisland Bluff.

It has a general resemblance to various small forms of *L. lenticularis*, Ach., *L. parasema*, Ach., and *L. contigua*, Fr.

The hymenium gives a deep blue with iodine; the thecæ and paraphyses are

very small, and very closely aggregated. I did not succeed, under power 425 of my Nachet's microscope ($\frac{1}{8}$-inch objective), in distinguishing the spores, which are also very small.

12. *Lecanora homologa*, Nyl., Lich. N.Z., 251 (figs. 13, 14).

On the trunks of living trees, Greenisland Bush: associated with *Physcia plinthiza*, Nyl.

It has a general close resemblance to some forms of *L. subfusca*, Ach.; but its spores (fig. 14) at once distinguish it. These are broadly ellipsoid or oblong, colourless; sometimes convex on one side, and straight on the other (plano-convex); 1-septate, and constricted (*c*) or not at the septum (in the old state); ·0009″ long, and ·00045″ broad. In the young state they are occasionally polari-bilocular (*a*); or there are three loculi (*b*), (the central one by far the largest), round, oval, sub-angular or quadrilateral, united generally by a tubule running up the centre of the spore as a kind of longitudinal canal. Very commonly they are 3-locular, with loculi resembling those of the spores of *Verrucaria nitida*, Schrad.

The *thecæ* (fig. 13 *b*) are large, distinct, and ventricose; 8-spored; ·0036″ to ·0045″ long, and ·0012″ broad; beautifully blue under iodine, as are also the hymenial lichenine generally, and the tips of the paraphyses (*a*). The *paraphyses* are very delicate, filiform, colourless, indistinct, devoid of clavate or coloured heads.

13. *L. peloleuca*, Nyl., Lich. N.Z., 251 (fig. 15).

On columnar basalt, Greenisland Bluff.

The *paraphyses* are delicate and indistinct, without coloured, clavate heads. The *thecæ* are closely aggregated, of medium size, deep blue with iodine. The *spores* (fig. 15) are broadly ellipsoid or oval; of various shades of olive or brown, according to age; being deepest brown in the old state (*c*), palest olive in the young (*a*); ·00075″ long, and ·00045″ broad: in the young state polari-bilocular (*a*), the loculi sometimes connected by a median longitudinal tubule or canal: in the old state 1-septate (*b*), with a constriction or not opposite the septum, sometimes having the figure of 8-form of (*c*), and otherwise resembling, the spores of *Physcia pulverulenta*, Fr.

14. *L. thiomela*, Nyl., Lich. N.Z., 252 (fig. 16).

On basaltic porphyry, Forbury Heads, Dunedin.

The thecæ and spores are best seen in young apothecia, which have much the aspect of spermogones, being yellow papillæ, perforated apparently by a darker, brownish-yellow ostiole, which is, however, the unexposed and unexpanded disk. The *paraphyses* are delicate, filiform, indistinct, without coloured, clavate heads. The hymenial gelatine gives a beautiful dark-blue colour with iodine. The *thecæ*

are broadly and irregularly obovate above, 8-spored; ·0045″ long, and ·0009″ to ·0012″ broad. The *spores* (fig. 16) are broadly ellipsoid or oval; ·0009″ to ·0012″ long, and ·00045″ to ·0006″ broad; 1-septate; olive or brown, according to age. In the young state, and in young apothecia, no septum is visible (*a*); the spores are polari-bilocular, as in *L. peloleuca;* the locules connected or not by a median canal; and there is almost no colour, or a very faint olive. In old spores there is generally a constriction opposite the septum (*c*), where they frequently split, giving exit to a globose nucleus (*c*), about ·00045″ in diameter, which is either colourless, or of a faint lemon-yellow tint. Sometimes the spores are seen in the process of elongation at both ends preparatory to germination (*d*).

15. *Placopsis perrugosa*, Nyl., Lich. N.Z., 250 (fig. 17).

On basaltic boulders, top of Kaikorai Hill (1092 feet); associated frequently with *P. gelida*, L., to which it has a close affinity, and for which it may readily be mistaken.

The *thallus* is greyish or brownish, thick, and crustaceous, consisting of, or divided into, a series of pulvinuli or isidiiform cushions, arranged, especially peripherally, in sublinear rows, having a general resemblance, in this respect, to the thallus of *Lecanora ventosa*, Ach. When sterile, it generally bears cephalodia resembling those of *P. gelida*. It is one of the saxicolous lichens, whose thallus is apt to occur sterile, and isidiiferous or sorediiferous.

The *apothecia* are closely crowded, assuming various angulose forms from mutual pressure. The disk is of a port-wine-red colour, assuming a more brilliant pink or crimson under moisture; and in this respect also—the characters of the apothecia—the plant resembles *L. ventosa*. Its *spores* (fig. 17), however, are very different. They are ellipsoid-oblong, simple, colourless, generally with double contour (*b*); ·0006″ long, and ·00045″ broad, arranged in a linear series, eight in each theca: in riband-shaped *thecæ*, 0045″ long, and ·00045″ broad, which give, as does the hymenial lichenine, a beautiful blue colour with iodine.

The disk of the apothecium is occasionally the seat of the parasitic *Microthelia perrugosaria*, nov. sp., described in the 3d section (Fungo-Lichenes).

16. *Opegrapha subeffigurans*, Nyl., Lich. N.Z., 258 (fig. 18).

On the bark of the "Totara" pine (*Podocarpus Totara*, A. Cunn.), Greenisland Bush; associated with *Arthonia platygraphella*, Nyl.

The *paraphyses*, as in all the New Zealand *Opegraphæ*, are delicate, filiform, indistinct, without coloured, clavate heads. The hymenial lichenine gives a yellow or pale wine-red tinge, with iodine; the *thecæ* a very pale blue. The latter are ventricose; ·0021″ to ·0030″ long, and ·0006″ to ·0009″ broad; 8-spored. The *spores* (fig. 18) are ellipsoid-oblong, dark-brown, 1-septate, ·0006″ to ·0008″ long, and ·00025″ to ·0003″ broad. In the old state, there is frequently a constriction oppo-

site the septum, giving them a figure-of-8 form (*b*); occasionally also they are solæform, with one end or half broader, and generally also shorter and rounder, than the other (*b*.) In the latter case, they resemble the spores of *Abrothallus Smithii*, Tul.

17. *O. agelæoides*, Nyl., Lich. N.Z., 257 (fig. 19).

On the trunks of living trees; Greenisland Bush.

The thallus is whitish and thin, following the rugosities and furrows of the bark. The lirellæ have a general resemblance to those of our common *O. varia*, Pers., which occurs in the North Island (KNIGHT and MITTEN), or of *O. saxatilis*, DC.

The *thecæ* are ventricose, ·0021″ long, and ·0006″ broad, 8-spored, and give a wine-red reaction with iodine. The *spores* (fig. 19) are fusiform, colourless, polyseptate (frequently 5-septa); ·0009″ long, and ·00025″ broad.

18. *O. spodopolia*, Nyl., Lich. N.Z., 257 (fig. 20).

On basalt; Shaw's Bay, The Nuggets, mouth of the Clutha.

Its microscopical characters differ little from those of the preceding species. The *spores* (fig. 20) are of the same character and dimensions. The *thecæ* are somewhat longer and broader—·0030″ long, and ·0012″ broad—and are unaffected by iodine; while the hymenial gelatine assumes a very pale wine-red tinge.

Professor CHURCHILL BABINGTON, in the "Flora Novæ Zelandiæ" of Dr HOOKER, remarks on the absence of the large and widely-diffused genus *Opegrapha* from the Lichen-Flora of New Zealand as one of its marked peculiarities. This statement arose evidently from the circumstance that, at the period when he wrote (1855), no species of the genus had been collected in New Zealand, or had been sent home, so as to be accessible for examination in the Kew or other public Herbaria. But KNIGHT and MITTEN* have since described several species from the province of Auckland. My Dunedin herbarium contains the three species just mentioned; and, I doubt not, the further researches of Botanists, and especially of Lichenologists, accustomed to the detection of minute or microscopic, inconspicuous corticolous and saxicolous Lichens, will discover other species of this genus in all parts (of the lowlands at least) of New Zealand. Similar remarks might be made in regard to other Lichen-genera at present supposed to be altogether absent from the Lichen-Flora of New Zealand; and until, indeed, its Lichen-Flora has been *fully* investigated by competent *resident* Botanists, we must be cautious in asserting that any given families, genera, or species are absent,—unless we do so distinctly with the qualification, that our statement is simply *provisional*, and is intended to direct the attention of local Botanists to the supply of a desideratum in our knowledge of the New Zealand Lichens.

* "Contributions to the *Lichenographia* of New Zealand, being an account, with figures, of some new species of *Graphideæ* and allied Lichens." By Dr KNIGHT of Auckland, New Zealand, and W. MITTEN, of Hurst-Pierpoint, Sussex (the eminent Muscologist).—*Trans. Linnean Soc., London*, vol. xxiii. p. 101, plate xii.

19. *Arthonia platygraphella*, Nyl., Lich. N.Z., 258 (fig. 21).

On "Totara" bark, Greenisland Bush; associated with *Opegrapha subeffigurans*, Nyl.

The apothecia are frequently roundish and sub-convex, with a Lecideiform aspect, exhibiting a thin, white, obscure, thalline margin. Sometimes they are oblong and irregular, sometimes confluent.

The *thecæ* and *paraphyses* are unaffected by iodine; the former (*a*) are broadly saccate, as is the general character of thecæ in the genus *Arthonia*; 8-spored; ·0009″ long, and ·0006″ broad. The *spores* (*b*) are irregularly fusiform or obovate, colourless, 3-septate; ·00045″ long, and ·00025″ broad. They have frequently much the appearance of half-spores—halves of fusiform, and 1-septate spores—with minor nuclei, or granular contents.

20. *Platygrapha longifera*, Nyl., Lich. N.Z., 258 (figs. 22–3).

On the bark of dead trees; Saddlehill Bush.

The *paraphyses* (fig. 22 *a*) are subdiscrete, delicate, filiform, without clavate heads. The *thecæ* (*b*) are somewhat sac-shaped, 8-spored; ·0030″ to ·0036″ long, and ·0006″ broad; generally *un*tinged by iodine, but occasionally violet. The *spores* (fig. 23) are acicular or narrowly fusiform, sometimes slightly curved; poly-septate (generally about 10-septa). They vary considerably in dimensions, from ·0009″ to ·0018″ long, and ·00015″ to ·00025″ broad.

21. *Pertusaria perfida*, Nyl., Lich. N.Z., 253 (figs. 24, 25).

On tertiary grits and conglomerates, base of Saddlehill; on trappean rocks, Shaw's Bay, The Nuggets.

The *thallus* varies in colour from dark slate or lead-colour to whitish. The sterile portions are made up of a series of Isidia; and the plant, in this state, would have been described by the earlier Lichenologists under the genus *Isidium*. The fructiferous portions of thallus bear a great general resemblance to certain forms of *Lecanora cinerea*, L.

The *paraphyses* (fig. 24 *a*) constitute a network of very delicate, indistinct, hyaline filaments, without clavate, coloured heads; and are thus typical, or possess the ordinary characters of those of the genus *Pertusaria*. The *thecæ* (*bc*) vary in length from ·0069″ to ·0090″, and in breadth from ·0015″ to ·00075″, according as the 8-spores are arranged in one (*c*), or a double (*b*) series, being in the one case ribband-like, and in the other ventricose or obovate superiorly; they strike a beautiful blue with iodine (*b*), while the hymenial gelatine gives a violet. The *spores* (fig. 25) vary considerably in length, from ·0006″ to ·0015″, with a general breadth of ·0006″; they are broadly ellipsoid; simple, colourless, generally exhibiting a double contour (*b*); granular, or full of oil globules in the young

state (*a*). They have the general characters of the spores of *Lecanora* and *Psoroma*, rather than of *Pertusaria*, especially as regards size.

22. *P. perrimosa*, Nyl., Lich. N.Z., 253 (figs. 26, 27).

On columnar basalt; Greenisland Bluff.

This is one of several local saxicolous Lichens, whose thallus is apt to occur abundantly sterile, and isidioid or variolarioid (sorediiferous). The plant differs greatly from the majority of our British types of *Pertusaria*, in the extreme smallness of its thecæ and spores. The paraphyses also are scarcely typical, inasmuch as they are colourless, delicate, and filiform, without coloured or clavate heads; they are, nevertheless, sub-discrete, regularly arranged linearly, with their apices readily seen (fig. 26 *a*). The *thecæ* (fig. 26 *b*) are unaffected, moreover, by iodine; are 8-spored; ·0021″ long, and ·0003″ to ·0006″ broad, according to age and maturity of contents. The spores (fig. 27) are simple, ellipsoid, colourless; ·0004″ long, and ·00015″ broad.

23. *Pannaria immixta*, Nyl., Lich. N.Z., 249 (fig. 28).

On the branches of trees, East Taeri Bush.

The thallus is sub-coralloid; the paraphyses very delicate, filiform, indistinct, without coloured, clavate heads; the thecæ indistinct, 8-spored; the hymenial gelatine pale blue with iodine. The *spores* (fig. 28) are ellipsoid, simple, colourless; 0006″ long, and ·00025″ broad.

24. *P. gymnocheila*, Nyl., Lich. N.Z., 250 (fig. 29).

On trees; Martin's Bush, Chain Hills; associated with *Collema leucocarpum*, Tayl.

The plant has a general resemblance to *Coccocarpia plumbea*, Lightf., or *C. molybdæa*, Pers.

The hymenium gives a beautiful blue with iodine. The *paraphyses* do not much exceed in length the thecæ; they are sub-discrete and filiform; their clavate heads (epithecium) are of a brownish or yellowish colour, and are intimately united and covered by a colourless, transparent membrane; the hypothecial tissue has also a brownish or yellowish tint. The *thecæ* are ·0036″ to ·0045″ long, and ·0006″ broad; 8-spored, with the spores arranged in one or two rows. The *spores* (fig. 29) are ·0009″ long, and ·0003″ broad; ellipsoid, simple, colourless; exhibiting generally, in the mature state, a double contour (*a*).

25. *Psoroma sphinctrinum*, Mnt. (figs. 30, 31).

On stockyard fences of "Goai" timber, Martin's Bush, Chain Hills; on *living* trees, East Taeri Bush; on the bark of *dead* trees, Saddlehill Bush.

An abundant corticolous species in Otago, fruiting freely. The colour of the

thallus varies from pale grey to lurid (blackish-brown). The minutely squamulose character of the thallus gives the plant the aspect of a *Pannaria*. The hymenium and thecæ give a beautiful blue with iodine. The latter are 8-spored (with the spores generally arranged in a single series), ·0036″ long, and ·0006″ broad. The sub-discrete, filiform paraphyses are united by yellow clavate heads. The *spores* (fig. 30) are broadly ellipsoid, oval or oblong; simple, colourless; with double contour generally in the mature state (*a*); ·0006″ long, and ·00045″ broad. What appear to be *spermogones* are marginal, brown tubercles, resembling the spermogones of *Peltigera* and *Nephroma*, containing myriads of atomic or ellipsoid spermatia (fig. 31), about ·0001″ long, and ·00005″ broad; possessed of vivid Brownian movements, borne apparently on arthosterigmata, which are indistinct.

The species is confined to warm countries, such as South America and Australia. In specimens in the Hookerian Herbarium, from the Cape (MILLER) and the Mauritius, I found the spores of the same character as those in my Otago plants, differing only as to size, being here ·00038″ long, and ·00020″ broad.

Var. *pholidotoide*, Nyl., Lich. N.Z., 250.

On living trees, East Taeri, and Saddlehill, Bush.

The *thallus* is rudimentary, consisting of a few minute, sparsely scattered scales, seated on the black hypothallus, the plant having thus the aspect of certain of the smaller *Endocarpa*. The *apothecia* are large, closely crowded in the centre of the thallus, almost constituting the plant; becoming, from mutual pressure, irregular and difform, sometimes sub-confluent. They have a thickish, rugose or crenulate thalline margin, and a disk of chestnut colour, without any tinge of black. This form frequently bears considerable resemblance to various *Pannariæ*, e.g., *P. brunnea*, Sw., or *P. nebulosa*, Hffm. Its thecæ and spores are exactly those of the type.

26. *Physcia plinthiza*, Nyl., Lich. N.Z., 249 (fig. 32).

On the trunks of living trees, Greenisland Bush; bearing both apothecia and spermogones.

The *thallus* is distinct and foliaceous; sometimes lobulate, of a slate-grey colour, apt to be obscured by overgrowing Jungermanniæ. The apothecia become with age convex, and have a widened, flattened exciple. The hymenium, thecæ, and tips of the paraphyses all assume a more or less deep and beautiful blue with iodine; this tinge is sometimes comparatively deep on the tips of the paraphyses, while it is very pale on the apices of the thecæ. The *thecæ* are 8-spored, ·0036″ long, and ·0009″ broad. The *spores* (fig. 32) vary considerably in their characters, combining the features of those of *Verrucaria nitida* and *Physcia pulverulenta*. Their usual length is from ·0009″ to ·00135″, breadth about ·00045″; their general form broadly ellipsoid or ellipsoid-oblong. Sometimes they are

convex on the one side, and straight on the other (plano-convex) (*c*); sometimes where septa exist in the old state, there are constrictions opposite each of generally 3-septa. The colour varies from pale olive (*a*) to deep brown (*c*), according to age; darkness of tint, as is generally the case in the spores of lichens, being proportionate to age. For the most part, especially in the young spores, there are no distinct septa (*a*); but a number of loculi, varying from 4 to 8 (most frequently 4), which are sometimes globose, sometimes lenticular or quadrilateral, connected or separate, according apparently to age; sometimes becoming longitudinally divided, giving the spore a sub-muriform character (*c*).

27. *Ricasolia herbacea*, DN., var. *adscripta*, Nyl., Lich. N.Z., 248 (fig. 33).

On the bark of dead trees, Saddlehill Bush; bearing both apothecia and spermogones. There are also specimens from Tarndale, Nelson, *ex* Herb. Dr Sinclair, of Auckland; some bearing apothecia, others sterile.

The plant appears to me hardly to deserve a separate name as a variety; I do not see wherein it differs sufficiently from its type. The *paraphyses* are subdiscrete, filiform, united by yellow tuberculated tips. The *thecæ* are 8-spored, blue with iodine; ·0036″ long, and ·0009″ broad. The *spores* (fig. 33) are more or less fusiform, 1-septate; sometimes with the loculi of unequal size (*b*), colourless or pale yellow; ·0009″ long, and ·00025″ broad. The spermogones are those of the type, which I have elsewhere described.*

28. *Sticta subcoriacea*, Nyl., Lich. N.Z., 247 (figs. 34–36).

On trees, Saddlehill Bush; bearing both apothecia and spermogones; also from Wellington, sent me by Dr Müller of Melbourne (identical in external characters with my Otago specimens).

The plant has much of the aspect, and most of the general external characters of various *Ricasoliæ*, e.g., *R. herbacea*, DN., and *R. coriacea*, Hook. and Tayl. It seems indeed a connecting link between the genera *Sticta* and *Ricasolia*. The main difference consists in the presence in the *Sticta* of *cyphellæ;* but in some *Stictæ* these are absent, or they (or Pseudo-cyphellæ†) occur on the *upper* instead of *lower* surface of the thallus (*e.g.*, in the following species *S. episticta*, Nyl.) The mere presence or absence of *cyphellæ* is not, I think, a sufficient character for the separation as genera of *Ricasolia* and *Stictina* from *Sticta*. Not unfrequently in the same species of either of these genera, cyphellæ occur or not. In my Otago specimens of *Ricasolia coriacea* occur a few cyphellæ, which are exactly like those of *S. subcoriacea*. I do not know, indeed, in what essentials *S. subcoriacea*

* "Mem. Spermogones," p. 202, Plate X. figs. 6–11.

† I am not satisfied that there is any essential distinction (anatomical, morphological, or functional) between *Cyphellæ* and *Pseudo-cyphellæ*. Though the former are typically urceolate and smooth, they become pulverulent and shallow; and pass thus, by imperceptible gradations, into the latter. (*Vide* "History of British Lichens," 1856, pp. 42–336.)

differs from *Ricasolia coriacea*, save as to the greater size of thallus, and the more general presence of cyphellæ in the former. Both plants, moreover, grow in the same habitat, though the *Ricasolia* is more generally found fertile than the *Sticta*.

There is the same rigidity of thallus, the same white-pilose apothecia and thaline margins. Under water, the lower surface of the thallus of the *Sticta* exhibits well its beautiful velvety-pilose character, while the upper surface assumes a greenish tint.

In my Otago specimens the hymenium gives a beautiful blue with iodine. The *paraphyses* (fig. 34, *b*) are sub-discrete, united by yellowish tuberculated heads, which are covered by a colourless membrane (epithecium) (*a*). The *thecæ* (*c*) are 8-spored; like the hymenium, blue with iodine; from ·0024″ to ·0036″ long, and ·00045″ to 0009″ broad. The *spores* (fig. 35) are more or less ellipsoid, 1-septate; ·0006″ to ·0009″ long, and ·0003 broad; of olive (*b*) or brown (*a c*) colour, and otherwise resembling the spores of *S. fossulata*, Duf.

In Wellington specimens, the *thecæ* are ·0024″ to ·0030″ long, and ·0008″ broad; the *spores* (fig. 36) ·0010″ long, and ·00045″ broad; broadly ellipsoid or ellipsoid-oblong; 1 or 3-septate, according to age; brown. In young apothecia and within their thecæ, they are almost uniformly 1-septate, and more or less deep brown in colour; but in old apothecia and out of their thecæ, they are frequently, if not generally (typically), 4-locular or 3-septate (*b*). In other respects, Wellington and Otago specimens agree in internal as well as external characters.

29. *S. episticta*, Nyl., Lich. N.Z., 248.

On trees, Saddlehill Bush; on columnar basalt, Greenisland Bluff.

The saxicolous forms have much the aspect of thick, rigid, coriaceous states of *Parmelia saxatilis*, Ach.; while the corticolous ones resemble *Ricasolia herbacea*, DN.

In this species there is a reversal of the ordinary position of the *Pseudo-cyphellæ*, which are here on the *upper* surface of the thallus, and being whitish, are somewhat conspicuous on the buff-coloured epithallus (cortical tissue). Corresponding to the Pseudo-cyphellæ above, the under surface of the thallus is marked by a series of minute buttons or papillæ of the same pale reddish-brown colour as the under surface of the thallus, and nestling among the fine fibrillose tomentum, with which it is copiously covered. On the upper surface there occasionally occur small sub-globose isidia or *cephalodia*, of a bright gamboge-yellow colour.

All my specimens are sterile, so that I have had no opportunity of examining its apothecia or spermogones.

30. *S. filix*, Hffm., Nyl., Lich. N.Z., 246 (fig. 37). (LINDSAY, Spermog., p. 194, Plate X. fig. 28. *Stictina filicina*, Ach., Nyl., Synopsis, 349.)

On trees, East Taeri Bush; Signal Hill, Dunedin (*ex* Herb. Dr Sinclair).

One of the most beautiful of the New Zealand *Stictæ*. Some specimens show the tendency to multifid division of the edges of the laciniæ, so common among these *Stictæ*. Similar minute squamules or granules occur occasionally also on the margins of old apothecia, as well as on the surface of the thallus. These old apothecia frequently lose their disk, and assume the colour of the thallus, or a paler or whitish tint. The colour of the upper surface of the thallus in the Herbarium varies from buff to bright reddish-brown. The prominent ribs of the lower surface, which, in the Herbarium, have generally a dark-brown colour, give the plant somewhat the aspect of certain marine *Algæ* (*e.g.*, species of *Fucus*). These costæ have, moreover, frequently corresponding sulci on the upper surface of the thallus. The stout, rigid stem in the larger forms, frequently becomes sub-fistulose, from incurving of its margins.

In Signal Hill specimens the *thecæ* are ·0030″ to ·0036″ long, and ·0006″ broad; the *spores* (fig. 37 *a*) broadly ellipsoid, 3-septate, colourless or pale yellow; ·0009″ long, and ·0003″ broad.

Var. *parvula*, Nyl., Lich. N.Z., 247 (fig. 37).

Tarndale, Nelson (ex Herb. Sinclair); bearing both apothecia and spermogones.

One of the most elegant of the lesser *Stictæ* of New Zealand. The thallus is very smooth and glistening, divided into very narrow, minutely cut laciniæ. The whole plant resembles in size and shape (it is under an inch high) some forms of *Cladonia cervicornis*, Ach., and its allies.

The *paraphyses* are sub-discrete, with coloured and irregular, tuberculiform heads, closely united. The *thecæ* are 8-spored, blue with iodine; ·0036″ to ·0045″ long, and ·0006″ to ·0009″ broad. The *spores* (*b*) are narrowly ellipsoid, 3 to 5-septate, colourless; ·0015″ long, and 00025″ broad.

31. *S. damæcornis*, Ach., var. *subcaperata*, Nyl., Lich. N.Z., 247 (figs. 38–42).

On trees, East Taeri Bush; bearing both apothecia and spermogones.

In colour and other characters it resembles *Ricasolia herbacea*. The *paraphyses* are discrete, filiform, united by yellow clavate apices, which are covered by a yellow thin membrane. The hymenium gives a beautiful blue with iodine, and its whole constituents are very distinct. The *thecæ* are 8-spored, ·0045″ long, and ·0009″ broad. The *spores* (fig. 41) are broadly fusiform, colourless, 3-septate; ·0012″ to ·0015″ long, and ·00045″ broad. The *spermogones* (fig. 38 *b*) are those of the type,

and have been described by me elsewhere.* They are sub-marginal, papillæform, with darker brown ostioles (fig. 39). The *spermatia* (fig. 42 *a*) are rod-shaped; ·00015″ long, and ·00005″ broad; borne on arthrosterigmata (*b*) about ·00015″ broad, and of varying lengths, generally about ·0015″ long.

II.—FUNGI (Plate XXX.)

Genus I. *Sphæria.*

Species 1. *S. Lindsayana*, Currey MSS. (figs. 1 to 7).

Diagnostic characters: Division, *Caulicolæ*.—"Perithecia very small, round; rupturing the epidermis by a circular, rimose, or radiate fissure. Sporidia 8, biseriate, colourless, irregularly cymbiform, 0·0014 to 0·002 inch long."

"The perithecia are so adherent to the epidermis, that it is impossible to make out the nature of the ostiolum. There is apparently no Rostellum; or if any, it is not visible above the epidermis. The plant, when dry, has somewhat the appearance of *Sphæria nebulosa*, Fr." (Currey MSS.)

Habitat.—Covers, in the form of very minute, point-like, black dots, the dry, incurled, yellowish, dead leaves of *Phormium tenax*, Forst. (fig. 1), (the familiar and abundant "New Zealand flax"); in the swamps of Glen Martin, Saddlehill.

I have little doubt it will be found, if looked for, in profusion on dead flax leaves throughout the New Zealand islands.

In the specimens, which I have myself examined under the lens and microscope, the plant has very much the aspect of certain minute, corticolous *Verrucariæ*. There is, perhaps, a distinction, however, in the non-action of tincture of iodine† on the hymenium of the *Sphæria*, and in the intimate adhesion of the perithecia of the latter to the epidermis of the *Phormium* leaf—an adhesion, which renders it difficult to manipulate them for microscopical examination, save after boiling and maceration.

In the mature state, the Fungus appears as a distinct, but minute, epidermal papilla; its circumference marked by a dark, well-defined ring; its apex pierced by a black, very small ostiole, normally punctiform, but becoming with age, compression, or other causes, rimose or irregularly radiate (fig. 2 *a*). In old and emptied perithecia, this ostiole widens variously, producing an *urceola* instead of

* "Mem. Spermogones," p. 194, Plate X. figs. 16–19.

† The reaction of this tincture with the hymenial "gelatine" (so-called, but which is really that modification of starch designated by chemists *Lichenine*), is too variable and uncertain to constitute a safe or good character for distinguishing *Lichens* from *Fungi*. Though this gelatine, and the thecæ specially, in the great majority of *Lichens*, give a reaction with tincture of iodine, which varies in colour, from beautiful Prussian *blue*, to an obscure port-wine *red*, of every intensity of shade, there is, in a minority of cases, no distinct coloration; while, on the other hand, the *blue* coloration, formerly supposed peculiar to *Lichens*, occurs, Mr Currey informs me (MSS. 1859), among indubitable *Fungi*. In other parts of this Paper I have shown that in the same species of *Abrothallus*, in which there is generally no coloration by iodine, it nevertheless sometimes occurs in foreign specimens.

a *papilla* (figs. 3, 4, *b*); or into a ragged, black, rent-like mouth; the apex of the epidermal papilla falling away, and the margins of the torn or fissured leaf-epidermis fringing the irregular remanent basilar cavity (fig. 2 *b*). The upper half of the perithecium is formed by the epidermis of the *Phormium*, which is gradually elevated, as the Fungus is developed and approaches maturity; and this epidermal papilla is perforated apicially by the ostiole of the *Sphæria*, the discharge outlet for its spores (fig. 3). The lower half of the perithecium is sub-epidermal, seated in the subjacent fibro-cellular tissues of the *Phormium*-leaf. Maceration causes the site of the perithecium to become more apparent; the epidermis of the *Phormium* becomes detached, as a somewhat translucent thin membrane (fig. 4 *c*), from the subjacent tissues, carrying with it the projecting papilla, which contains the ostiole and upper half of the perithecium; while the black, circumscribed base remains as an irregular mass, resembling somewhat the old Lichen-genus *Pyrenothea* (fig. 4 *b*, 2 *b d*). Moisture or maceration, moreover, alters the appearance of the epidermal papilla, which now becomes wholly black, instead of exhibiting a mere black ostiole and ring (fig. 2 *c*). The epidermal papilla frequently appears to fall off, leaving a black ring alone, as an indication of its former presence—of its medial circumference.

The perithecia vary in size, number, and closeness of aggregation. For the most part, they are, to the naked eye, punctiform, greatly crowded, and frequently confluent or sub-confluent. Normally, they are round, but from pressure on each other in a state of close aggregation, they become ellipsoid, or otherwise variously elongated. Sometimes they are flattened on the surface or apex, and they then have, under the lens, somewhat the aspect (save as to colour and size) of the wart-like apothecia of a *Pertusaria*, the epidermis of the *Phormium* appearing as if covered with a series of minute blisters.

Their position is equally on and between the rugæ and furrows, which mark the surface of the *Phormium* leaf. Occasionally they are disposed in rows, especially when they occur in the leaf-furrows. More generally, their distribution is quite irregular or scattered.

Notwithstanding many examinations, I have not succeeded in satisfying myself as to the form and size of the *thecæ*, which are extremely delicate and hyaline. But, in a few cases, the *spores* were abundant and distinct. Those I saw were normally ellipsoid, 6 to 8 locular; colourless; hyaline; with a very delicate envelope; ·0003″ to ·00025″ broad, and ·0016″ to ·0013″ long; resembling closely the septate spores of many Lichens (fig. 5). Occasionally (apparently only aged ones), I found them slightly curved, a condition which is likewise common in the old state of the fusiform and ellipsoid spores of Lichens; but this appeared to me to be an accidental condition, or one depending on age. Occasionally, intermixed with the normal fully developed spores, were half spores, apparently the result—if not, sometimes at least, of artificial division by friction of the glass

slides during examination—rather of abortive development, than of the partition of the full-sized, mature spore (fig. 6). Sometimes these half spores occurred in considerable numbers.

In certain old perithecia, in their *Pyrenothea*-like bases seated below the epidermis of the flax leaf—and in the same perithecia, moreover, that had apparently contained thecæ and normal endothecal spores (fig. 4 *b d*)—I found myriads of extremely minute corpuscles, resembling in size and other features the spermatia of various Lichens,—differing, however, in their irregularity of form (fig. 7). They were ellipsoid, fusiform, or rod-shaped; occasionally slightly curved; about ·00016″ long, ·000083″ to ·000066″ broad, endowed with a vivid Brownian or molecular movement. Materials are probably imperfect for determining whether these corpuscles really belong to the *Sphæria*. If they do, they are probably to be considered its *stylospores*. In reference to these corpuscles, and to the observation connected with their discovery, Mr CURREY writes—"It is not, I think, improbable that you may have found *spermatia* and *asci* within the same perithecium in *S. Lindsayana*, although such an occurrence is not common in the genus. Indeed, I do not know that it has ever been observed. *Conidia* (the bodies resembling *spermatia*, but which are larger, and *capable of germination*) have been noticed by TULASNE in the same perithecium with asci. You will find a figure of this in the second volume of his 'Selecta Fungorum Carpologia.'* . . . . . In *S. Lindsayana*, you have probably come upon perithecia in what is called a *Sphæropsoid* state, *i.e.*, having only very minute *stylospores and no asci*. These imperfect perithecia are found in some *Sphæriæ*, and are probably more common than has been supposed. But further observation alone can determine whether they are universal." †

Sp. 2. *S. Otagensis* (figs. 8 to 15).

Diagnostic char.: "Div. *Villosæ*.—Perithecia erumpent, or flattened, with a mammillate ostiolum, tomentose. *Sporidia* (? biseriate) brown, curved, 3–6 septate, constricted at the septa, variable in length; 0·0006 to 0·001 or more inch, sometimes with one (or more ?) longitudinal septa. Not in good condition." (Currey MSS.)

Hab. On a stockyard fence of old, weathered "Goai" timber (*Sophora tetraptera*, Aiton); farm of Fairfield, Saddlehill.

To the naked eye, the perithecia appear to be a series, closely aggregated, of very minute, irregular tubercles or buttons: but, when moistened and carefully examined under the lens, they resolve themselves into two main forms—the cone or papilla, and the disk. The former resemble the perithecia of various of the larger black *Verrucariæ;* the latter the young apothecia of various *Lecideæ*. The papil-

* Letter, March 22, 1865. † Letter, November 6, 1865.

late condition is characteristic of the young state only. The cone is sometimes quite symmetrical and well-formed, and generally exhibits distinctly the apicial ostiole (figs. 11, 12 *a*). The discoid form is characteristic of maturity and age, and is more common than the conical. Here the papilla becomes flattened; the ostiole is so transformed that it loses all its ordinary characters, and is not recognisable as such; most frequently it occurs as a saucer-like cavity, surrounded by a thickened margin, resembling the apothecial exciple of Lichens (Lecideæ). Sometimes, the cavity becomes funnel-shaped, the perithecium having the form of an inverted cone (figs. 10, 12 *b*).

Frequently the perithecia are confluent, and then they lose their normal appearance, and become variously deformed (fig. 9). They are generally seated in the lacunæ or interstices of the woody fibres; and there, from pressure apparently by these fibres, they become variously elongated (fig. 8). Sometimes, from their state of close aggregation and form, they resemble our common *Dichæna rugosa*, Fr.

They are originally hypophlæod, developed in the superficial tissues of the bark or wood. Through these they gradually burst in process of development, until they become sub-sessile; their base only being seated in a hollow of the wood. Sometimes they are seated on pedicle-like projections of the superficial layers of the wood; the portions of the latter not protected by the growth of the parasite being eroded or worn away by weathering. Generally the fabricated timber on which this *Sphæria* grows is more or less bleached or whitened by weathering; and on this whitish base the pitch-black perithecia are prominently visible.

In the old state, the upper half, or three-fourths of the perithecium, fall away, leaving the base as a black, saucer-like hollow or scar in the wood; or as a saucer, sessile, or semi-sessile, adnate, not immersed (fig. 13).

The spores vary in length from ·0009″ to ·0006″, and in breadth from ·0002″ to ·0003″; they are septate (3 to 6, or more septa, though frequently 3); becoming sub-muriform from longitudinal division of the loculi; colour varying from olive green to dark brown: outline irregular from bulgings opposite the loculi (fig. 14). They exhibit a double contour (the cell-wall or general envelope being distinct from its loculi) usually in their mature state (*b*); but it is indistinct, or apparently absent, in the young (*a*). They have a close general resemblance to the spores of *Urceolaria scruposa*, L., and *Lecidea petræa*, Wulf. They do not differ much, even in size, from those of my New Zealand specimens of the former Lichen. I saw them frequently germinating from one or both ends—the terminal cell becoming gradually discharged of its colouring matter, and sending forth from its distal end, or extending itself into, a tube about ·00015″ in diameter; with a double wall, hyaline, or of a brown tinge, especially towards its tip (*c*).

In very minute, black, punctiform conceptacles, semi-immersed in the wood,

resembling in external character the spermogones of many Lichens, and apparently bearing a similar relation to the *Sphæria* (figs. 11, 12, 13 *c*), I found myriads of globular or oval corpuscles—spermatia—about ·00006″ to ·000075″ in diameter—given off apparently from the ends of extremely minute, simple sterigmata (fig. 15).

The *Sphæria* occurs on the same wood with *Patellaria atrata*, Fr., from which, however, its perithecia may be distinguished by their less size, greater thickness, more verrucarioid aspect, and greater closeness of aggregation. The disks of the *Patellaria* are largish, thin, very irregular in form, with incurved or corrugate margins; frequently angular or lirellæform, and resembling the difform apothecia of various *Umbilicariæ*, *Graphideæ*, *Lecanoræ*, or *Lecideæ*. The *Patellaria* is distinguished further by the microscopic characters of the hymenium. The *thecæ* (fig. 16) are large and distinct; ·0045″ to ·0030″ long, and ·0009″ broad, resembling those of Lichens. The *hymenium* contains a large quantity of oil globules (*b*). The *spores* (fig. 17) are large and very distinct, resembling those of certain *Arthoniæ* and *Verrucariæ*. They are, moreover, *colourless*, somewhat irregular in form; ellipsoid, obovate, or pyriform (broad at one end, and tapering at the other); ·0009″ to ·0012″ long, and ·0003″ broad; 8–10 septate. In the old and young states (*c*), their contents are a mass of granules instead of distinct loculi; and in the former state, also, they frequently become greatly elongated—narrowly fusiform; ·0018″ long; apparently preparing to germinate, and extend themselves into the tubular or mycelioid condition (*c*).

Sp. 3. *S. Martiniana* (figs. 18 to 22).

"Fruit 0·0007 inch, rather larger than in *S. pulvis-pyrius*; otherwise exactly like latter, but it can hardly be a rostrate form of that species." (Currey MSS.)

Hab. On trunks of living trees (apparently chiefly "Goai"); Greenisland Bush.

The bark, on which the perithecia occur, is very rugose and whitish; they are jet-black, and consequently very prominent, and easily seen under the lens. They are very minute and punctiform; but vary considerably, both in form, size, and surface, having greatly the external characters of the Lichen-genera *Pyrenothea* and *Microthelia*. They are generally granular or powdery on the surface, and on this account, as well as by reason of the minuteness of the perithecia themselves, their ostiole is seldom or never visible. The young perithecia exhibit only a punctiform, black papilla on the surface of the bark; while their large black body is sub-epidermal or immersed—requiring to be enucleated from the woody tissue for examination (fig. 20). In maturity and age, however, they become—gradually emerging from the woody tissue—sub-sessile,—the base only being immersed, or occupying a saucer-like hollow of the matrix. As in the case of

S. Otagensis, in age the upper portion of the perithecium frequently falls away, leaving only the saucer-like hollow in the matrix occupied by its base: this assuming the appearance of a black scar, or being whitish with a black ring, according as the base remains or disappears (fig. 19 *b*). The perithecia vary greatly also as to their closeness of aggregation, being isolated, closely aggregated, or confluent ;and in the latter case necessarily becoming difform.

The thecæ and paraphyses are very delicate, and are seldom, or with difficulty, distinctly seen. The *thecæ* are apparently 8-spored, and the *spores* biseriate, as in most Lichens. The thecal wall seems closely to envelope the spores like a sac, as is common in the *Arthoniæ* (fig. 21). The *spores* are 3-septate; brown; ·00045″ long, and ·00015″ to ·00025″ broad; irregularly ellipsoid; generally bulging more or less, according to age, opposite each locule; very seldom muriform, but having a tendency to longitudinal division of the loculi (*c*); sometimes slightly curved (fig. 22).

With this species I have associated the name of my friend WILLIAM MARTIN of Fairfield, Saddlehill, Otago, one of its few resident Botanists and pioneer settlers, to whom I was indebted for much assistance in my Otago excursions and collections, and on whose property in Greenisland a great portion of these collections was made.

I have no doubt that many new species of the large and ubiquitous genus *Sphæria*, and of allied spheriaceous Fungi, have yet to be added to the New Zealand Flora; but their discovery and determination will require all the care of experienced local Fungologists.

GENUS II. *Nectria*.

Sp. 1. *N. Otagensis** (*N. armeniaca*, Currey MSS.), (figs. 53 to 60).

Diagnostic characters.—"Perithecia cæspitose; pale-apricot coloured, with ostiolum darker; sporidia biseriate, colourless, about 0·0007 inch." (Currey MSS.)

Hab. On stockyard fences of old "Goai" timber, ravines of the Chain Hills.

A beautiful little Fungus of a pale orange-red colour, and waxy aspect; forming a bright contrast to the greenish bark on which it grows (figs. 53, 55). It generally nestles in the rough and deep furrows between the irregular rugæ of the very rugose bark of "Goai," and is best seen when the latter has a dark olive tint. The plant has much the appearance of masses of certain fish-roes;

* The name originally bestowed by CURREY was the very appropriate one, *armeniaca* (apricot-coloured); but, in the meantime, the same designation has been conferred by TULASNE (*Selecta Fungorum Carpologia*, vol. iii. p. 75, plate x.) on a French and very different species; and it appears easier and preferable to render the name of the Otago plant more distinctive, rather than to raise trivial questions of priority of nomenclature.

occurring generally in the form of irregular glomeruli (fig. 54), which are compound—made up of an aggregation of individual perithecia. These perithecia are found isolated only in the young state of the plant (figs. 55, 56). They are then seen to be isidiiform or sub-columnar warts, having a rounded apex, marked by a sub-papillate ostiole (*a*), of a darker red, which leads to a flask-shaped imbedded nucleus (*b*), of similar colour. Under moisture, the whole perithecium becomes more beautiful and distinct; it swells, and assumes a brighter or purer colour; the ostiole becomes quasi-pellucid or gelatiniform, and much more papillate and prominent; and the nucleus shows itself on section as a viscid or gelatiniform mass, of colour resembling that of the ostiole, having more of a brownish or reddish tinge than the exterior or envelope of the perithecium.

These perithecia coalesce or become aggregated in numbers of from two to twenty or upwards, to form the compound glomeruli. From mutual pressure. they undergo changes of shape, but they never entirely lose their individuality; for each perithecium in a glomerule may be distinguished by its red punctiform ostiole (figs. 54, 58), and on section, by the dissepiments between the separate nuclei.

The glomeruli vary necessarily greatly in size and form, according to the number and closeness of aggregation of the constituent perithecia (fig 53). They, as well as the ostioles, also vary much in deepness of colour, being sometimes comparatively pale, at other times darker, and more red or brown, than usual. The ostioles, moreover, vary greatly in size and form; sometimes they are mere points—in large glomeruli of closely aggregated perithecia; sometimes they are so large and distinct as to resemble the disks of *Lecanorine* apothecia (fig. 58). Their form is determined by that of the perithecia; which again is regulated by the amount and direction of mutual pressure in their condition of aggregation in the glomeruli. In the old state, the nucleus frequently falls out, leaving an inverted conical cavity of a much paler (whitish) colour than the exterior walls of the perithecium (figs. 57, 59). In this state, the perithecium bears some resemblance to certain species of the old Lichen-genus *Gyalecta*.

The *spores* (fig. 60) vary considerably in their characters. Their length is generally about ·0006″ to ·00075″; their breadth ·00015″ to ·00025″; they are colourless, and very delicate, resembling those of certain *Verrucariæ*. Their form is generally narrowly ellipsoid; but they may be convex on one side only, and straight on the other; or fusiform; or variously curved in the same or opposite directions. Sometimes they are simple, or occupied by two to four or more nuclei or granules, or with fine granular matter alone. There is, however, a tendency to division of the cell-contents into two or four loculi (*a b*), producing the appearance of 1 to 3 septa; and sometimes also there is a tendency to constriction opposite the septum (*a*).

Genus III. *Æcidium.*

Sp. 1. *Æ. Otagense* (figs. 61 to 74).

1. Parasitic on the flowers, flower-petioles and leaves of *Clematis hexasepala*, DC. East Taeri Bush; Novem.; in abundant flower; a beautiful bush-climber, known to the Maoris as the "Pūawānanga," or "Pōanānga."

The flowers and flower-petioles are completely deformed by the growth of the parasite; their aspect is so entirely changed, that were the diagnosis of the plant dependent on specimens possessing these diseased organs, its species and genus would probably not be recognisable. The filiform or slender petioles, in particular, not only become twisted and curled variously, but are the seat of irregular, succulent, gouty swellings—of cucumber or cactus-like growths (figs. 61 *a*, 62 *c*), whose nature is rendered apparent by the beautiful buff-coloured Peridia, by which they are covered.

When the *flower* is the seat of the parasite, the sepals become thickened and somewhat coriaceous or fleshy, at least toward their bases or insertions. They also acquire adhesions to each other at their proximal ends, forming a sub-campanulate or sub-urceolate perianth (fig. 62 *a*). On the *outer* surface of the sepals the Peridia exhibit themselves as *Urceolæ* (fig. 66 *a*), resembling the cyphellæ of some *Stictæ;* while, on their *internal* surface, the position of each urceole is marked by a corresponding *papilla* (fig. 66 *b*). When the Fungus occurs on the *leaf* of the *Clematis* (fig. 63), it alters its texture and appearance to this extent, that the leaf becomes thickened and coriaceous; its margin notched, thickened, and curled up (*a*); and its colour assumes a russet-brown or faded autumnal tint.

In the young state, the Peridia appear as epidermal papillæ (figs. 65, 67 *a*), gradually pierced by an apicial ostiole, which rapidly expands into an urceola (figs. 66 *a*, 65 and 67 *b*), developing or exposing the concealed disk. Frequently, also, they are verrucæform or disk-like, having a more or less flat surface, with or without a thick, rounded, prominent rim (figs. 64, 65, 67 *c*). Normally, in the mature and old state, the Peridia are urceolate; their disk being sunk below the level of the epidermis of the *Clematis;* with raised margins projecting above the same level, varying much in thickness (fig. 67 *b*). Sometimes this margin is as thick as the apothecial exciple of many *Lecanoræ;* at other times it is thin and sub-membranous. Normally, the shape of the Peridia is round; but from pressure on each other, when more or less closely aggregated, they become variously ellipsoid or elongated (fig. 64 *d*). They vary greatly in their numbers and closeness of aggregation. Sometimes they are isolated, or occur in twos or threes (fig. 63), or in very small, scattered groups. This is the case on the *leaf* of *Clematis* in my specimens. At other times they are so closely crowded, that there is left between each Peridium no intervening tissue of the matrix (figs. 61, 62, 64).

This form is common on the *flower-petiole* of *Clematis*. Between the widely segregated and the closely aggregated forms there is every variety of distribution. It is in the former that the thick margin and verrucæform character generally occur; while in the latter we usually find the thin margin and regular urceola, with flattened disk (best seen on the flower petiole in my specimens).

In this country, similar deformities are produced on our common Nettle and Elder by *Æcidium Urticæ*, DC.* In the one case, the leaf-petioles and stem, and in the other, the stem, become twisted, curled, and swollen in a similar way. My friend M. C. Cooke, author of a recent "Synopsis of the British Æcidiacei"† (who was kind enough to examine my Otago species or forms), remarks of the one under description—"The *Æcidium* on *Clematis*, producing gouty swellings, &c., just corresponds with our *Æ. Ranunculacearum*, DC., which I have on *Clematis vitalba* from France and Germany." It does not, however, follow that it is the same species; indeed, its characters do not correspond with those of *Æ. Ranunculacearum*, as given in the "Flora Novæ Zelandiæ"‡ (in which work the said *Æcidium* is described as hitherto found only in the *North* Island, growing on *Ranunculus rivularis*, Banks and Sol.)

When exhibiting the monstrosities of *Clematis hexasepela* above described, and explaining or demonstrating their causes—the growth of the parasitic *Æcidium*—to the colonists of Otago, I was informed by them of the existence of similar deformities of parts or organs of a variety of trees and shrubs, which, from the descriptions given, may prove to be attributable to a similar cause—the development of a co-generic or co-specific parasitic Fungus. There is every reason to believe, therefore, that the study of *local vegetable teratology*—of the *diseases of local plants*—their causes and effects, offers a wide and novel field of research to the local Botanist.

2. Parasitic on the leaf (under surface)§ of *Epilobium junceum*, Forst., on plants growing 8 to 15 inches high on the Chain hills and flanks of Saddlehill; December; in flower.

The leaves on which the parasitic Peridia are scattered, are generally somewhat altered in colour and texture (fig. 69). The colour becomes russet-brown; the leaf looks faded, and presents a premature appearance of age (for the plant, on which the parasite occurs in my Herbarium, is a young one, with unexpanded flower-buds) (*a*). Sometimes the margin of the leaf becomes puckered or curled

* Excellent coloured plates of this and other British species—including the deformities they produce—may be found in an admirable popular "Introduction to the Study of Microscopic Fungi," by M. C. Cooke. London, 1865.

† Journal of Botany, vol. ii. p. 33, with a plate.

‡ Of Dr Hooker, vol. ii.—Cryptogamia, 1853.

§ It is of interest to note that the *British Æ. Epilobii*, DC., occurs on the *under* (rarely upper) side of the leaves of *Epilobium montanum*, L.; *E. hirsutum*, L.; and *E. palustre*, L. (British species of *Æcidium*, Cooke's "Introduction," p. 190.)

inwards or upwards.* Its texture becomes thickened and sub-coriaceous; and this change is most evident, when leaves affected by the parasite are compared with those unaffected; which, in the latter case, are thin, sub-membranous and altogether of greener colour, with a healthier, fresher, younger appearance, and more flaccid consistence. The mal-conditions, or deformity here produced by the parasite, are, however, much less marked than in the case of *Clematis* or of *Microseris*.

The Peridia on the specimens examined by me were generally regularly round and deeply urceolate (fig. 70); the sunk disk was always of a lighter colour than the raised margin, both being, however, pale buff or brownish. Sometimes both disk and margin assumed the same colour as the faded-looking leaf—a russet brown.

"Possibly," says Mr Cooke, "your *Æcidium* on *Epilobium* is *Æ. Epilobii*, DC., which has some of the habits of the present species."

3. Parasitic on the leaves of *Microseris Forsteri*, Hook. fil.; growing in marshy places, Abbott's Creek, Greenisland; October to December; in flower.

Generally the Peridia occur as oblong or ellipsoid papillæ or tubercles, unmarked or unpierced by an ostiole in the young state, but exhibiting various forms of urceolæ—for the most part with irregular margins—in the old state (figs. 71, 72). Essentially they resemble in appearance and structure the Peridia which occur on *Clematis*. They also resemble, however, more than do the Peridia on *Clematis* or *Epilobium*, the wart-like apothecia of *Pertusaria*, including both the normal and variolarioid conditions of the latter.

Mr Cooke makes the following interesting remarks regarding this form of the parasite:—"I should say that your specimen on *Microseris* is closely allied to *Æ. Tragoponis*, Pers., and that it certainly is *not* the very common and variable *Æ. Compositarum*, Mart. All the marginal teeth are gone, and most of the spores. If it could be determined whether the Peridia were seated on any definite coloured spot (I think they were not), and what the colour of the spores in the fresh state, and whether that colour was fixed or mutable, we could say definitely whether it really is *Æ. Tragoponis*. My own impression is that it would prove to be *an undescribed species;* but there is not sufficient material to state for certain, or to describe it if new. The colour of the spores, when fresh, is of specific value—as at present acknowledged—whether rightly or wrongly. . . . . You will observe that . . . . the Peridia are scattered, and *not* collected in definite clusters. These are not so numerous or close as in *Æ. Tragoponis*, as you will see by reference to Plate I. fig. 1 of my 'Microscopic Fungi.' . . . . In *Æ. Tragoponis* the spores are at first yellow, then blackish. If, from a better specimen, you can determine that the spores are permanently yellow in your

* Similar thickening and involution of the edges of the leaves on which they grow are sometimes caused by British species, *e.g.*, *Æ. Asperiifolii*, Pers., and *Æ. Euphorbiæ*, Pers. (Cooke, "Introd.," p. 191–2.)

species, it might be regarded as *a distinct species of which I know of no description.* It is not the *Æ. australe* of BERKELEY, which is a *Ræstelia*, I think."

So far as my data enable me to judge, it appears to me to be the same Fungus, which is parasitic on the three Phænogams above mentioned; and it seems doubtful, so little do they vary in their characters, whether the three *forms* deserve separate consideration or classification as *varieties*. The Peridia occur—most generally on the *leaves* of the plants on which they grow—as a series of minute cups or saucers sunk in the tissues of the matrix; pale buff-coloured in the centre, with a darker projecting margin. In shape and colour, these have considerable resemblance to the urceolate apothecia of the old Lichen-genus *Gyalecta* (fig. 64 *b*). To the naked eye they generally appear to be a series of minute, round, buff-coloured spots, sometimes from their abundance giving the leaf on which they grow a yellowish or reddish tinge, with a dry, withered, or puckered character (fig. 69 *b*). For their proper examination, however, they require the aid of the microscope and lens; and the examination should be made *on fresh or living specimens*—for this is one of the many genera of Fungi, whose species can only in this way be accurately determined or fully described. In so far as my specimens were all examined in the dried state, in the Herbarium, my data for determination and description are confessedly imperfect.* It remains, therefore, for *local Botanists* to settle such questions in the natural history of the genus *Æcidium* and its species (as developed in New Zealand) as the following:—

1. Whether the genus is autonomous, and not a mere form or condition of other *Uredineæ*, as OERSTED and DE BARY suggest?

2. Whether, assuming that it *is* a good genus, it contains so many good species as is at present supposed? This is a subject regarding which the most eminent Fungologists are somewhat at issue. On the one hand, Mr CURREY writes me—"I have no faith in the *species* of *Æcidia*: I think that in all probability they are reducible to two or three, if not to *one, species*." On the other hand, Mr COOKE, though admitting, doubtless, their great variability and complexity, describes no less than *thirty-one British species alone.*

3. Whether *Æ. Otagense* differs so essentially from species already described as to deserve a permanent place as a separate species? It differs from the only two species recorded in the "Flora Novæ Zelandiæ," *Æ. Ranunculacearum*, DC., and *Æ. monocystis*, Berk. (which is apparently confined to New Zealand). Nor does it appear to agree in all particulars with any of the thirty-one British *Æcidia*. The

* In all three cases of the parasite on *Clematis*, *Epilobium*, and *Microseris*, the Fungus was determined to be a true *Æcidium* (as the genus is at present established), by the presence of its characteristic spores. "*Æcidia*," says Mr CURREY, in reference to some difficulties that occurred to me in my microscopical examination, "*never bear thecæ*. . . . : In the early state of *Æcidium*, the perithecia produce minute *spermatia;* but neither in that state, nor in the more advanced condition, have *asci* (thecæ) ever been observed. . . . . The spores are always produced in chains; and when they fall apart, after the opening of the cups, they produce the yellow dust (or white) with which the cups are filled."—*Letter*, March 22, 1865.

probability at present therefore is, that if it is proper to maintain upon botanical records the names of so many species as at present established, this merits at least one separate place among their number.

4. Whether the forms occurring on *Clematis*, *Microseris*, and *Epilobium* are *species, varieties, or conditions?*

It will be a further and interesting problem for the *local Botanist* to determine —Whether the same species or forms of *Æcidium* affect plants of different species, genera, and orders; or, on the other hand, whether certain species, genera, or orders of Phænogams are characterised by their specific parasitic *Æcidia*. The present probability is all in favour of the first supposition. The genus in all its forms is eminently deserving of study by resident Fungologists; because, in addition to the points of interest already enumerated, some at least of its species are most destructive to the flowering plants on which they are parasitic.

In all probability several, if not many, species or forms of this large genus *Æcidium* remain to be added to the Flora of New Zealand.

III. FUNGO-LICHENES. (Plate XXX.)

I have elsewhere* pointed out the desirability or propriety of instituting and maintaining an intermediate provisional class between Lichens and Fungi for the purpose of separately grouping a number of doubtful organisms—mostly parasites on the thallus or apothecia of Lichens—regarding which our knowledge cannot yet be said to be either complete or satisfactory, and which, so far as they have been at all specially studied, are the subject of most opposite opinions among Lichenologists and Fungologists. They are placed now among Lichens, now among Fungi, by different authors, whether Lichenologists or Fungologists. They partake of the characters of both these classes of Cryptogams. They are in great measure lost sight of in the ranks of either; while their interest as connecting-links between Lichens and Fungi is such as to render it most desirable to keep them prominently under the notice of Botanists till present conflicting views are reconciled, and their true place in classification is established. Some, if not most, of the parasites in question are to this day equally the puzzles of Lichenologists and Fungologists—the "opprobria," of Lichenology and Fungology. Lichenologists, regarding them as *Fungi*, give them no special examination; while Fungologists, considering them mere degenerations or imperfect conditions of Fungi (if Fungi at all), and with equal probability *Lichens*, also appear to give them no adequate attention. The consequence of this common neglect is, that there is perhaps no group either of Lichens or Fungi of which we really know so little of a precise character. The group of Fungo-Lichenes is incapable of precise scientific definition. It is a

* On *Arthonia melaspermella*, Nyl.—*Journal of Linnean Society*, vol. ix. (Botany), p. 268.

heterogeneous assemblage of genera (such as *Microthelia*, *Celidium*, and *Phymatopsis*) * of very varied character.

Nor are these genera themselves satisfactorily or perfectly defined—consisting of an equally heterogeneous collection of species of diverse character—species which improvement in our knowledge regarding them will probably, in course of time, lead us to draft off for the most part to existing genera of Lichens or Fungi, though a minority may become the basis of really new, separate, and properly definable genera, whether of Lichens, Fungi, or Fungo-Lichenes. The genera *Microthelia*, *Celidium*, and *Phymatopsis* are here then regarded and adopted—as the group to which they have been here referred is also—simply as *provisional*; an adoption, however, which is convenient, if not necessary, for reference, and for the facilitation of their further study. The genera referred to agree with those lower Fungi, which are possessed of several forms of fructification, in rarely, if ever, exhibiting all these forms contemporaneously in the same specimen or locality, or it may be, country. I am not aware at present of any instance of complete or perfect fructification—that is, the co-existence of apothecia and spermogones or pycnides—in a given specimen in any given species. Usually fructification, where it occurs, is imperfect, only one form of the reproductive organs occurring (as the sporiferous perithecia in *Microthelia*). Frequently (in *Celidium* and *Phymatopsis*) there is no normal fructification at all; neither spores, spermatia, nor stylospores can be distinguished by repeated and careful examination—the plant existing only in a sterile or degenerate, rudimentary or protothalline condition—the dark-brown irregular and indistinct cellular tissue of the maculæ or wartlets furnishing no clue to the Order even to which the plant belongs. From these circumstances, it happens that an observer may examine—as I have done—in the long course of years, many thousand Lichens from every part of the known world, before he finds a fertile condition of some of these parasites, that is, their apothecia, spermogones, or pycnides; before he is in a position, therefore, to venture to assign the sterile Fungiform Maculæ, so familiar to him, to their proper Natural Order, family, genus, or species. In plants of such a character there cannot fail to be extreme difficulty—frequently for the time, and for years insuperable—in tracing the connection of the several forms of fructification, or their relation to a common species; and it is not surprising, considering the nature of the material, that errors should and must continue to occur in the assignation of names and affinities. Though the connecting links may appear to have been discovered, it may, and probably will, in a certain proportion of cases, prove, in course of time,

* The same genera are classed as "*Pseudo-Lichenes*" by Krempelhuber ("Die Lichenen-Flora Bayerns," 1859, p. 275): and by Anzi, *Celidium* and *Abrothallus* are included among "Genera inter Lichenes et Fungos incedentia;" while *Microthelia* is placed among the *Verrucariæ* ("Catalogus Lichenum quos in Provincia Sondriensi et circa Novum-Comum collegit" Martin Anzi, 1860; Como: Introduction, xvi.)

that certain apothecia, spermogones, or pycnides, which usually or always occur by themselves, unassociated with their complementary forms of fructification, are really properly referable to plants even of a different order or family. In the absence of *spores*, it is generally impossible or unsafe to determine either species or genus; but their presence does not always render diagnosis facile—for numbers of plants presently classed in the genus *Microthelia* possess essentially the same small, brown, solæform, 1-septate spores, while their habitats or other characters are diverse.

There are several parasites on Otago Lichens, which I prefer, for the reasons above assigned, to describe in a group as Fungo-Lichenes, rather than either as Lichens or Fungi.* In my Dunedin Herbarium, some of these exhibit only perithecia (*Microthelia*); others only spermogones (*Phymatopsis*); while a few occur only as sterile maculæ or warts, which are presumably rudimentary or degenerate perithecia or apothecia, or confluent clusters thereof (*Celidium*). In the two latter classes of cases my New Zealand specimens do not in themselves furnish sufficient means or characters for their determination. But on the same or similar Lichens from other parts of the world, I have found what seem to be links connecting the maculæ or spermogones in question with the relative apothecia, and which enable me—though doubtfully, and with reservation after the explanation already given—to refer them to apparently new forms of *Celidium* and *Phymatopsis*. The nature and relations of these Otago parasites cannot, however, possibly be understood (in so far, at least, as they are imperfect or infertile) without reference to the fertile condition of the most closely allied European plants; and I have the less hesitation in here recording the results of a comparative examination of the latter, that they themselves are little known to Lichenologists and Fungologists, and hence possess an inherent interest warranting their description.

GENUS I. *Microthelia*, Körb. Syst. Lich. Germ. 372 (Syn. *Verrucaria*, Pers.; *Pyrenula*, Ach.; *Endococcus*, Nyl.; *Tichothecium*, Mass.; *Phœospora*, Hepp; *Buellia*, De Not.; *Lecidea*, Ach.; *Abrothallus*, De Not. (*Lichens*), pr. p.: *Sphæria*, Hall (*Fungi*), pr. p.

Typical species have papillæform, superficial perithecia: whence the generic name (μικρος, small, and θηλή, a wart or papilla). In recedent or exceptional forms, the perithecia are punctiform and immersed, or semi-immersed. In all cases the perithecia are extremely minute or microscopic; and they resemble in size and external aspect the black papillæform or punctiform spermogones of many

* In the Society's "Proceedings," vol. v. p. 528, I have classed them provisionally as *Sphæriæ*, to which they have a more or less resemblance, and to which some at least may hereafter really prove to be referable. Nos. 4, 5, 7, and 8 are now described as *Microtheliæ*; No. 6 as a *Phymatopsis*; and No. 9 as a *Celidium*.

Lichens, especially the lower crustaceous groups. By Körber, Stizenberger,* Mudd, and others, the genus is classed among the *Verrucariaceæ* (*Lichens*);† but while Körber proposes enlarging his genus at the expense of the *Sphæriæ* (*Fungi*), Mudd‡ is apparently disposed to hand over the genus itself, with all its species, to the *Fungi*. My own impression is, that in course of time the genus *Microthelia* will be partitioned mainly, if not entirely, between the *Verrucariaceæ* and *Sphæriacei*—between *Lichens* and *Fungi*.

Sp. 1. *M. perrugosaria*, nov. sp. (figs. 23 to 28).

Hab. Perithecia parasitic on the apothecia of *Placopsis perrugosa*, Nyl., which I found somewhat plentifully on basaltic boulders on the top of Kaikorai Hill (1092 feet).

The parasite is best seen by moistening the apothecia of the *Placopsis*. The disk or epithecium is naturally of a dark or dull port-wine red or crimson colour. Under moisture this colour becomes lighter, the epithecium swells and becomes waxy, and the black punctiform parasitic perithecia then become prominent (figs. 23, 24). They occur in considerable numbers on a single apothecium; generally discrete or isolated; sometimes confluent. The perithecium is found, on careful examination, to be, in its upper half, a papilla seated *on* the epithecium of the *Placopsis*, while the lower half is immersed *in* its tissues (figs. 25, 26). Its walls are formed of dark-brown, small, irregularly formed, and densely aggregated cells (figs. 26).

The *paraphyses* are delicate, filiform, indistinct; without clavate heads; coloured yellow by iodine (fig. 27 *a*). The *thecæ* are ·0021″ long, and ·00045″ broad; ribband-shaped or ventricose, according as the spores are arranged in one or two rows; 8-spored; coloured yellow by iodine (fig. 27 *c d*), and thereby distinguished from the thecæ of the *Placopsis*, which (with its hymenial gelatine), under the same reagent, assume a beautiful Prussian blue, and which are ·0045″ long, and ·00045″ broad (fig. 29). The *spores* are broadly ellipsoid or oval; olive or brown; 1-septate; seldom or never constricted at the septum; polari-bilocular in the young state, and otherwise resembling, on a small scale, the spores of *Physcia pulverulenta*, Schreb, and other Lichens; ·00045″ long, and ·00025″ broad (fig. 28). They are readily distinguished from the spores of the *Placopsis*, which are oblong-ellipsoid; with double contour; *simple; colourless;* and ·0006″ long, ·00045″ broad (fig. 30).

* "Beitrag zur Flechten-systematik," 1862, p. 147.

† The most recent arrangement of the *Verrucariæ* is by Prof. Garovaglio of Pavia ("Tentamen Dispositionis Methodicæ Lichenum in Longobardio nascentium," with Plates and Dried Specimens, 1865), who includes in the comprehensive genus *Verrucaria*, no less than 35 Massalongina genera, and among these *Microthelia*, Körb., and its allies, *Thelidium*, Mass.; *Tichothecium*, Flot.; and *Thrombium*, Wallr.

‡ "Manual of British Lichens," 1861, p. 306.

The plant does not appear to differ materially, save in its site, from two British species, *M. gemmifera*, Tayl., and *M. rugulosa*, Borr. (Mudd, "Manual," p. 306). It has further the characters of various Lichenicolous *Sphæriæ*, as these are described, especially by MUDD. It is, however, most doubtful whether, on the one hand, many, at least, of the *Sphæriæ* so-called, should not properly, as KÖRBER thinks, be referred to his Lichen-genus *Microthelia;* and, on the other, whether the latter genus itself should not be wholly transferred to the *Fungi*. The whole question, as it at present stands, is beset with difficulty and confusion.

The *Sphæriæ* and allied Fungi, which occur parasitic on the apothecia and thallus of Lichens, are at once so little known and so interesting, that I append, for the sake of comparison, a few illustrative examples.

1. *Sphæria squamarioides*, Mudd, p. 130; parasitic on the thallus of *Placopsis gelida*, L.; a Lichen which occurs equally in Otago and Britain, and is so closely allied to, and so frequently associated with, *P. perrugosa*, Nyl., as to be apt to be confounded therewith. *Microthelia perrugosaria* has many of the characters of *S. squamarioides* as described by MUDD, though the habitat differs—being *thallus* in the latter, *apothecia* in the former.

2. *Sphæria gelidaria*, Mudd, p. 130; parasitic also on the thallus of *Placopsis gelida*, L. Its characters at once distinguish it from *M. perrugosaria*.

3. *Sphæria cerinaria*, Mudd, p. 136; parasitic on the apothecia of *Lecanora cerina*, Ach., in Britain.

4. *Sphæria leucomelaria*, Mudd, p. 105; parasitic on the thallus of *Physcia leucomela*, Mich., and *P. ciliaris*, L.

5. *Sphæria epicymatia*, Wallr. (Nyl., Prodr. 85; *S. lichenicola*, Sommrf; Dur. and Mont. Fl. D'Algér. p. 529, Pl. I. No. 130; probably also the *S. apotheciorum*, Mass. Rich. p. 26, fig. 41).

Parasitic on the epithecium (of the apothecia) of *Lecanora albella*, Pers., throughout Europe and Northern Africa; and also, according to TUL. (Mém. Lich. p. 126), on that of *Physcia parietina*, L. Interesting from the possession of spermogones and pycnides, in addition to perithecia.

6. *Sphæria homostegia*, Nyl. (Prodr. 56; *Dothidea*, Syn., 389).

Parasitic on the thallus of *Parmelia saxatilis*, Ach., and *P. Borreri*, Turn. Possesses spermogones.

7. *Sphæria urceolata*, Schær. (Linds. Mem. Spermog. p. 175, Plate IX. fig. 35; Mudd, Manual, p. 267; Hepp exs. 475; described by some authors as an *Endocarpon* or *Dacampia*).

Parasitic on the thallus of *Verrucaria psoromia*, Schær, and *Solorina saccata*, L.

8. *Sphæria Hookeri*, Nyl. (Prod. p. 175). Parasitic on the thallus of *Endocarpon rufescens*, Ach. It would appear to be the same parasite, which occurs so frequently on the thallus of *Lecidea Hookeri*, Schær. (Nyl. Prodr. 139); which has been confounded with that Lichen in our Scottish Alpine (Ben Lawers)

specimens: which is described by MUDD (Manual, 271) as *Verrucaria Hookeri* (Borr. E. Bot. Suppl. plate 2622; Leight. exs. 318): and which has been variously mentioned by other authors as a *Lecidea*, *Verrucaria*, *Endocarpon*, and *Dacampia*.

9. *Sphæria ventosaria*, nov. sp.

Parasitic on the thallus of *Lecanora ventosa*, Ach.—a Lichen which is closely allied, especially in its apothecia, to *Placopsis perrugosa*. In 1856, I collected this Sphæria and Lecanora largely in the Scottish Highlands; and in 1860, in some communications on the subject with Mr CURREY, I proposed for it, as a new British species, and in reference to its habitat, the name *S. ventosaria*.* I have not, however, up to this date, published a description of this parasite; and meanwhile, it appears to be the same plant, which is described by MUDD (Manual, p. 307), as *Microthelia ventosicola*, he arranging it, though expressing great doubt as to the true position of the genus *Microthelia* (p. 308), among *Lichens*. It is, however, says Mr CURREY (in MSS. 1861), "a *true Sphæria*, but the species is quite new to me. It presents a very interesting peculiarity of fructification. Most of the *Sphæriæ* have only 8 spores in each ascus. A very few have an unlimited number; but the spores in these cases are almost colourless, and always simple (*i.e.* not septate), and slightly curved. In your specimen the spores are brown, 1-septate, elliptical, and very numerous in each ascus." HEPP (exs. 644, sub nom. *L. ventosa* var. *spermogonifera*) figures and describes oblong-*ellipsoid* spermatia, which do not agree with the ordinary spermatia of the *Lecanora*, as observed by myself in 1856, or as described by MUDD (157); the latter spermatia being cylindrical or acicular—that is, *linear*.

There are many other Lichenicolous *Sphæriæ*, which, however, have never been properly studied, either by Lichenologists or Fungologists. Besides which, species affecting parasitically the thallus or apothecia of both higher and lower Lichens are to be found—and yet remain to be fully studied and accurately determined—in the following *Fungus*-genera, *inter alia*:—

Dothidea, *Fr.*	Epilithia, *Nyl.*
Stictis, *Pers.*	Gassicurtia, *Fée.*
Spilomium, *Nyl.*	Illosporium, *Mart.*
Sclerococcum, *Fr.*	Peziza, *Link.*
Hymenobia, *Nyl.*	

Sp. 2. *M. Cargilliana*, nov. sp. (figs. 31 to 34).

Parasitic on the apothecia of *Parmelia perforata*, Ach., which latter grows

* Mr CURREY proposed for it the name *Sphæria lichenicola* (in letter, January 28, 1861). But this was unsuitable or inadmissible, not only because many other Sphæriæ are equally lichenicolous—parasites on the thallus or apothecia of Lichens; but the term itself had been previously applied by SOMMERFELT, and other of the earlier Lichenologists and Fungologists, *inter alia*, to various species of *Sphæria* (*S. epicymatia*, Wallr.), and *Microthelia* (*M. propinqua*, Körb., and *M. pygmæa*, Körb. Syst. Lich. Germ. 374).

plentifully on the branches and trunks of old or dead trees in Greenisland Bush.

In site and in general characters, this species resembles *M. perrugosaria*, from which, however, it differs in the character of its spores. The perithecia are black and papillæform; the upper half seated *on* the epithecium, generally of old deformed apothecia, the lower immersed *in* its tissues; generally isolated or discrete; scattered in considerable numbers on a single apothecium (fig. 31). Like those of *M. perrugosaria*, they have externally the characters of a minute *Verrucaria*. No thecæ were seen, but the perithecia contained abundance of brown, round spores, about ·00015″ to ·00025″ in diameter; simple, or with double contour (fig. 34). They cannot be confounded with the spores of the *Parmelia*, which are greatly larger, ·0045″ long, ·0003″ broad; *colourless;* and oblong or oval; though they are also simple, with or without a double contour, according to age (fig. 35). The beautiful blue reaction with iodine of the thecæ and hymenial gelatine of the *Parmelia* further sufficiently distinguish it from the hymenium of the parasite. Nor can the *Microthelia* be confounded with the parasitic *Abrothallus Curreyi*,* which affects the *thallus* of the same *Parmelia*, and which may in some of its conditions or parts be mistaken for the spermogones of the *Parmelia*. The *Abrothallus* is distinguished as a *Lichen* by the blue reaction of its thecæ and hymenial gelatine with tincture of iodine, and by the presence of distinct paraphyses with very granular and dark brown tuberculated heads, as well as by its general analogies.

Materials scarcely exist for the accurate determination or full description of *M. Cargilliana*, whose name is in honour of my friend JOHN CARGILL, F.R.G.S., of Greenisland, Member of the Legislative Assembly of New Zealand, and one of the best known pioneer settlers of Otago, to whom I was indebted for many acts of kindness in the course of my Otago excursions.

Sp. 3. *M. Ramalinaria*, nov. sp. (figs. 44–6).

Parasitic on the thallus of *Ramalina calicaris*, Fr., as it grows on the branches of trees (especially dead "Goai") in Greenisland Bush.

It occurs as extremely minute (microscopic), black, punctiform perithecia, scattered in great numbers, and in a state of close aggregation, over the surface of some of the branchlets, to which they give a dirty or blackish aspect (fig. 44). They are distinct only under the lens. Their wall consists of closely aggregated, dark brown, very small cells (fig. 46); but they contained no spores; and my present materials are, therefore, imperfect for full description or accurate determination. It appears, however, to be the same parasite, which occurs occasionally in this country on *R. scopulorum*, Ach. (Linds. Mem. Sperm. p. 130), and which I

* Described in the Section on *Lichens*, p. 409.

have found also on the apothecia of var. *fraxinea*, L. (of *R. calicaris*), rendering them black-punctate, on specimens in the Hookerian Herbarium, Kew, from Concepçion, Chili.

Sp. 4. *M. vermicularia*, Linds. (sub nom. *Lecidea*, Mem. Spermog. p. 143, plate v. figs. 19, 24, and 25).

Parasitic on the thallus of *Thamnolia vermicularis*, Schær. (specimens, as usual, sterile, bearing neither apothecia nor spermogones); Tarndale Mountains, Nelson; Dr ANDREW SINCLAIR.

I did not find this Lichen in Otago; but I have no doubt it occurs in the central and western alps, which I had no opportunity of visiting.

In New Zealand specimens the parasite exists only in a degenerate or abortive state. It occurs as very minute microscopic), black, punctiform, immersed perithecia, which sometimes become elongated or variously difform; under moisture assuming a brown tint and sub-corneous aspect. The envelope or wall of the conceptacle consists of brown, minute, closely aggregated cells; as do the perithecia of all the allied *Microtheliæ* (figs. 26, 46); but it contains no spores. The plant is, however, so similar otherwise to the parasite, which occurs abundantly in a fertile or normal state on the same *Thamnolia*, in the Falkland Islands, that I have little difficulty as to its identification.

M. vermicularia diverges—as does also *M. Ramalinaria*—from ordinary types of the genus, in so far as the perithecia are not papillæform and epithalline, but wholly immersed. In other respects, their characters are those of *Microthelia*, though they have, I think, equal claims to rank as *Fungi*.

These two species, moreover, are of interest as types of a group of parasites on the thallus or apothecia of Lichens, whose true position or affinities are not at present thoroughly understood or recognised, because, as a group, it has never been made the subject, as it deserves, of special study. Hitherto these parasites have been by myself, as well as other Lichenologists, classed, though *provisionally*, with *Lichens;* but I feel, and have always felt, that they have probably at least equal claims to be considered *Fungi*, and that, as such, they should be made the subject of a mutual re-examination and arrangement by and between Lichenologists and Fungologists. I refer to such parasites as the following, described or mentioned in my "Memoir on Spermogones:" *—

1. *Lecidea obscuroides*, Linds. (Spermog. 247; plate xiii. figs. 36–8; Mudd, 212). Parasitic on the thallus of a leprose form of *Physcia obscura*, Ehrh.

2. *L. Alectoriæ*, Linds. (Sperm. p. 135; plate i. figs. 12–13). Parasitic on the

* Compare also the species of the genus *Microthelia*, Körb., and certain species of the genus *Thelidium*, Mass, as described by MUDD (Manual, pp. 306 and 298); as well as certain species of the genera *Tichothecium*, Fw., and *Endococcus*, Nyl.)

thallus, as well as on the back or lower surface of the apothecia, of *Neuropogon Taylori*, Hook. fil.

3. *L. Cladoniaria*, Linds. (Sperm. p. 163, plate vii. figs. 14–16; Nyl. Enum. Suppl. p. 359). Parasitic on the folioles of the horizontal thallus; on the Podetia, or on their scales; in *Cladonia uncialis*, Hffm., and *C. bellidiflora*, Ach.

4. *Microthelia alciornaria*, Linds. (Sperm. p. 161).

5. *M. prunastria*, Linds. (Sperm. p. 137).

6. *M. Solorinaria*, Linds. (Sperm. p. 175). Parasitic on the thallus of *Solorina crocea*, Ach.

7. *M. Collemaria*, Linds. (Sperm. p .272). Parasitic on the thallus of *Collema melænum*, Ach.

Genus II. *Phymatopsis*, Tul. (*Abrothallus*, De Not.)

I adopt Tulasne's name for the genus, as being much more correct and appropriate than that of De Notaris, especially when applied to such forms or species as *P. dubia* and its allies. The original name, *Abrothallus* (ἁβρός, thin or delicate), was based on an entire misconception—all species of the genus being strictly athalline and parasitic on an alien thallus, as I have elsewhere pointed out.* But Tulasne's designation† (φῦμα, a tuber or excresence, and ὄψις, like) appropriately represents the external aspect of certain, at least, of its species. Like *Microthelia* and *Celidium*, I regard the genus as in the meantime simply a *provisional* one, made up of species of diverse character. The majority of modern Lichenologists class the genus with the *Lecideæ*, and include all its species, so far as at present known. Nylander, however, while he ranks *A. oxysporus* as a *Lecidea*, removing it altogether from *Abrothallus*, considers *A. Smithii* a Fungus.‡ I am at a loss to understand on what principle such a distinction is made. One of the principal supposed tests for distinguishing Lichens from Fungi —the blue coloration of the hymenial Lichenine of the former under iodine— cannot be depended on; for, on the one hand, it does not follow that a plant, whose hymenium does not give this reaction, is not a Lichen, or which does give it, is not a Fungus; while, on the other, I have sometimes met with blue coloration in foreign forms or specimens of the same plant, which in Europe does not usually yield any colorific reaction.

Sp. 1. *P. dubia* (figs. 36–42).

Parasitic on the apothecia of *Usnea barbata*, Fr., var. *florida*, L., as it grows plentifully on trees in the Bush, Pelichet Bay, Dunedin; a dwarf form of the *Usnea*, with articulate branches, and in abundant fructification. Some of the mature

* Monograph of *Abrothallus*, p. 7. † Mém. Lich. p. 113.

‡ He also alters the name—both specific and generic—recording it as *Habrothallus parasiticus*, Prod. 55.

and normal apothecia are marked by irregular, flat, brown, superficial maculæ, two or three of which generally nearly cover the epithecium (fig. 36). They are scarcely raised above the surface of the epithecium, of which they appear simply a discoloration; but when moistened and closely examined under the lens, they are found to be the seat of numerous extremely minute (microscopic), brown papillæ, which are semi-immersed. These papillæform conceptacles contain, instead of spores, myriads of rod-shaped *spermatia*, varying in length from ·00010″ to ·00015,″ and about ·00007″ broad, borne on the apices of very short, simple, sterigmata (fig. 38). These conceptacles have externally, save as to colour, the aspect of certain *Microtheliæ* (e.g., *M. perrugosaria* and *M. Cargilliana*); but their contents show them to be *spermogones*, whose relative sporiferous perithecia remain yet to be discovered or determined. As regards their sterigmata and spermatia especially—as well as in other characters—these spermogones do not agree with those of the only species of *Abrothallus* in which they are yet known to occur.* The knowledge we possess of the genus is, however, both fragmentary and unsatisfactory. It does not follow, then, that a difference of character excludes them from the genus; while, on the other hand, it must be stated as a possibility that they may ultimately prove referable to some other genus or order.

The parasitic spermogones in question are, moreover, quite different in all their characters from the spermogones of the genus *Usnea* or any of its species.† The latter are minute wartlets, of the same colour as the thallus, scattered upon the tips of the ultimate ramuscles, as well as over the apothecial marginal cilia. The sterigmata are much larger, and are compound or articulated; the spermatia, though also linear, are longer.

Beneath the brown maculæ of the parasite the hymenium of the *Usnea* has its normal character, striking its usual blue colour with iodine, and the thecæ containing the ordinary spores, which are oblong-ellipsoid, or sub-globose; simple; colourless; ·0003″ long, and ·0002″ broad; with or without double contour, according to age (fig. 43).

On *U. barbata*, Fr., var. *ceratina*, Ach., growing on the branches of trees in Saddlehill Bush. I found both apothecia and thallus infested with various forms of a parasite.

The one form consists of very minute, black, punctiform, or difform, semi-immersed perithecia, abundantly scattered over the surface of the roughened branchlets (fig. 39 *a*). In or *on* some of these I found *brown*, simple, oblong-ellipsoid spores; ·0003″ long, and ·0002″ broad; but they are of the same size and form as the normal spores of *Usnea*, to which they probably really belong, having

* In *A. oxysporus*, Tul., as described by myself ("Monograph Abrothallus," p. 33). TULASNE (Mém. 113) described the spermogones as unknown in the genus.

† Which are described and figured in my "Mem. Spermog." p. 121, plate i. figs. 1–8.

acquired *colour* only from the parasite, with which they have come into accidental contact (fig. 42).

The other form occurs as maculæ, more or less raised and difform, sometimes apparently destroying the superficial tissues of the apothecium or thallus—sometimes simply seated thereon (fig. 39 *b*). These maculæ have much the external characters of the *Celidia* of the *Stictæ*. They contained no spores, and were in an imperfect and unsatisfactory condition for determination. It remains for Local Botanists to determine whether the parasitic spermogones, perithecia, and maculæ above described are referable to the same plant, or to different species, genera, or orders.

The nature or relations of these isolated forms of fructification cannot be understood without comparison with a suite of European and foreign specimens of the same or allied species of *Usnea*, on which I have found at various times similar parasites in more perfect conditions. Of these it will be most instructive first to describe the highest forms of the most nearly allied parasites—those which exhibit sporiferous apothecia.

1. Sub. nom. *Abrothallus Usneæ*, Rabenhorst exs. ("Lichenes Europæi") No. 537; sent me some years ago by Dr RABENHORST himself from Germany; a fine specimen, abounding in the parasitic apothecia in every stage of their growth; affecting var. *florida*, L., of *Usnea barbata*, Fr., in abundant fructification. The parasite, if all its diverse forms are referable to one species, equally affects the thallus from base to apex; the apothecia normal and degenerate—upper and under surface; and the cephalodia of the *Usnea*.

The latter, as they occur in the genus *Usnea*, are so little known, and their true nature so much misunderstood, that they demand some description before we proceed further. I have repeatedly met with them both in British and foreign forms of *U. barbata*, and in foreign allied species, and I was long puzzled with their true character. A careful examination of a series of specimens leads me to concur with NYLANDER (Syn. p. 15), in regarding them as warts or excrescences of the cortical layer or tissue of the thallus, having, however, a modified structure, consisting of a very dense, finely striated (filamentous) tissue, not unlike that of many hymenia, where the paraphyses are very closely aggregated; a circumstance, which, along with the frequently pale-bluish or violet coloration with iodine, gave certain grounds for the apparently common belief that the growths in question were really degenerate apothecia. This coloration with iodine is, however, a fallacious indication of hymenial structure; for, in the cortical tissue of the thallus of the *Usnea* on which the *Abrothallus* is parasitic—far removed from all forms, both of apothecia and cephalodia—towards the base of attachment of the plant, I sometimes met with a distinct, though pale, violet-blue colour under iodine. I doubt not that the thallus of other of the higher Lichens, containing Lichenine in their tissues, will be found to yield a similar reaction.

The *cephalodia* of *Usnea* are not mentioned by MUDD (Manual, 1861); but they appear to have been familiar to the earlier English Lichenologists, who contributed to the "English Botany" of Sir JAMES E. SMITH. In that work they are both figured and described, apparently as of a twofold character, viz., partly as "*orbillæ*," or abortive apothecia, partly as "warts" or excrescences (p. 71). The "orbillæ" are best marked and commonest in var. *florida*, L. (p. 71, plate 2250). They agree in aspect with the cephalodia of *U. longissima*, Ach., from Sikkim (Himalayas) in the Hookerian Herb., Kew. In var. *hirta*, Fr., they are described as "flesh-coloured, solid warts" (p. 72, plate 2252); and in the type *U. barbata*, Fr., as "fleshy tubercles or warts." The writer adds in regard to the latter (the type *U. barbata*) a reference to the "absence of 'orbillæ,' which have never yet been discovered upon it in Britain or elsewhere" (p. 72, plate 2253): thus drawing an unnecessary distinction between the "warts" and "orbillæ," which are evidently, nevertheless, of essentially the same nature.

RABENHORST appears to regard the cephalodia affected by the parasitic *Abrothallus* as a diseased condition of the apothecia of the *Usnea*. But the latter, in their normal condition, are large, handsome, flat, broad, peltate; with a disk of similar colour to the thallus, or pale flesh-coloured as in *Ramalina*, the margin fringed with cilia, having the characters of the ultimate thalline ramuscles. In exceptional cases (as in a specimen of var. *florida* lately sent me from Lagos, West Africa, E. L. SIMMONDS) the apothecium is Parmelioid; the disk red and suburceolate; the margin raised, and furnished with few and short cilia, or subsimple. Here the apothecia are seated at angles of the thalline ramules, a circumstance which, though common or general in *cephalodia*, is rare in *apothecia*. Exceptionally cephalodia are apotheciiform—that is, they are flattish, with a raised, generally thickish margin, the parasite occupying the cavity resembling the disk. But I have never been able to trace any distinct transition between cephalodia and apothecia; hence I regard them as essentially differing in character and function. The cephalodia so common on the genus *Usnea* may be regarded as analogous to those of *Stereocaulon* (Nyl. Syn. 15), save that in *Usnea* they are solid, while in *Stereocaulon* they are hollow; in both cases, they must be considered morbid growths of and from the cortical layer of the thallus. In *Usnea*, they usually have the aspect of Cladonioid or Biatorine, compound or confluent, apothecia; being irregularly tuberculated, and more or less of a pale brownish or flesh-colour. Almost universally, where they occur, they produce angularity of the thalline ramules, so that they appear to have their normal seat at natural angles of the branchlets. The cephalodia are abundant all over the plant; so that in regard to their site, they are in marked contrast to the normal apothecia of *Usnea*. In Sikkim specimens of *U. longissima* I have found cephalodia terminal on two of the divergent cilia or fibrillæ of the thallus; in which case they had greatly the aspect of Cladonioid apothecia.

The apothecia of *Abrothallus Usneæ* in RABENHORST's specimen are frequently, especially towards the base of the thallus, isolated, large, and epithalline; convex, Biatorine, immarginate; of a blackish-brown colour; and having all the aspect of the usual apothecia of *A. Smithii*. Frequently, also, they become aggregated, confluent, and difform, then assuming the aspect of species of *Phacopsis** (e.g., *P. vulpina*). Another—the most rudimentary, and a sterile, probably a protothalline, condition of the plant—occurs in the form of maculæ—most irregular in form, size, and position; sometimes raised or convex; occupying occasionally such exceptional sites as the under surface of the apothecia, or the tips of the ultimate thalline ramuscles; in the latter case, giving the appearance of Cetrarioid spermogones. Between the large, isolated, sporiferous, Biatorine tubercles, and the aggregated or confluent sterile maculæ, there is every gradation of character. Of the isolated fertile apothecia, forms occur, which, though generally rounded or sub-spherical, are sometimes conoid or flat and wart-like, sub-immersed and emergent; sometimes girt with a thick distinct thalline border. The aggregate or confluent conditions, which are less frequently found fertile, generally produce irregular one-sided swellings of the branchlets, or apothecial cilia, on which also they find a site. Very seldom do they, in any of their conditions, surround the branchlet or fibril, being almost invariably seated only on one side thereof, producing angularities, swellings, and other deformities. Occasionally they are sub-terminal clusters of tubercles; in this, and in all other cases, of a blackish-brown colour, which, under moisture, becomes a pure, though dark, *brown*. The flattened disk passes gradually into the macula, frequently becoming stellate or irregular in outline.

The structure and contents of the hymenium must be examined in the isolated, large, regular, Biatorine apothecia. The aggregated, confluent, and difform conditions are almost invariably degenerate and sterile. The whole hymenium is generally obscured by more or less abundance of brown granular colouring matter; sometimes, however, it is very free from this colouring matter, and in such cases the thecæ and spores are very distinct, though the paraphyses are always indistinct, delicate, and obscured by much dark brown granular colouring matter about their tips. The *thecæ* are generally indistinct; 8-spored; the spores generally arranged in two rows; ·0018″ long, ·00045″ broad; giving no reaction with iodine. The *spores* are plentiful and distinct; oblong-ellipsoid;

* Contrast with the genera *Phymatopsis* and *Celidium* this genus *Phacopsis*, Tul. "Mém. Lich." p. 124 (name from Φακὸς, a nævus or lentigo, a skin-wart); and especially the species *P. vulpina*, Tul. (p. 126), Linds. "Mem. Spermog." plate iv. fig. 22, p. 125; Hepp exs. 474. Than this species no *Lichen* could more resemble, in its external aspect and habit of growth, a *Fungus*; but no Lichen gives, at the same time, a more distinct and beautiful blue or violet colour (varying in shade, and sometimes very pale) with iodine (thecæ and sometimes hymenium). While in *Phymatopsis* (*Abrothallus*) and *Celidium* the apothecia or groups of perithecia are essentially *brown* (though frequently of a dark blackish-brown), in *Phacopsis* they are essentially *black* ab initio.

simple in outline or solæform;* generally 1-septate; sometimes no septum visible in young state; olive or brown according to age; ·0003″ to ·0004″ long, ·00015″ broad. Associated with the full-sized spores are numerous half spores; probably the result of the friction of the glass slides under examination; generally sub-oblong or sub-spherical. In one sub-degenerate and oldish apothecium—not apparently in any distinct or separate conceptacle—I met with multitudes of corpuscles, having the characters of *stylospores;* colourless, irregular (sub-spherical, oval, oblong, or pyriform); about ·00015″ long, and ·00009″ broad.

So far as regards the highest or most perfect condition of the apothecia, it will be observed that those of *A. Usneæ* agree with those of the microspermous varieties of *A. Smithii.* But the spores are greatly smaller than those of the commoner forms of *A. Smithii,* which are generally ·00066″ to ·00090″ long, and ·00030″ to ·00040″ broad; while the stylospores (should they really prove to be so) are also greatly inferior in size to those of *A. Smithii,* in which they are ·00040″ to ·00066″ long, and ·00033″ to ·00040″ broad. No spermogones and no separate or isolated pycnides were detected. There are two forms of *A. Smithii,* which it is instructive to compare with *A. Usneæ,* viz.:—

2. Sub nom. *A. microspermus,* Tul. (Hepp exs. 477. *Lecidea thallicola,* Mass.), on the thallus of *Parmelia caperata,* Ach. The mature apothecia are usually papillæform; but in the old state they become flattened and maculæform, resembling the genus *Celidium* in external aspect. This maculæform condition is much more unlike typical species of *Abrothallus* than are the majority of forms of *A. Usneæ.* The apothecia are accompanied with pycnides; and associated also are the spermogones of the *Parmelia,* which are apt to be confounded with the said pycnides; but which are immersed, black, and punctiform.

3. *A. Smithii,* Tul. var.; parasitic on the thallus of *Ricasolia pallida,* Nyl. (Syn. 372. *Sticta pallida,* Kunth; *S. Kunthii,* Del. Linds. Mem. Spermog. 205); Mexico; in Herb., Kew. Apothecia small, black, lecidiiform; rounded or flattened; epithalline or sub-immersed. Hymenium, *blue with iodine;* a reaction which is exceptional in this species, and which is noteworthy as connecting it with *A. oxysporus,* and retaining it within the category of the *Lichens* (from which NYLANDER dissociates it, regarding it as a *Fungus,* Prodrom. 55). Paraphyses with deep brown tips. *Thecæ* 8-spored; ·0013″ long, ·0006″ broad. *Spores* brown; 1-septate; figure-8 shaped, or without constriction opposite the septum; variable as to size—frequently elongated and narrow; ·0006″ long, ·00016″ broad.

4. Var. *ceratina,* Sch. (*U. barbata,* Fr.); Rio Janeiro, HENRY PAUL, 1846; in

* "Shoe-sole-shaped"—"Schuhsohlenförmig" (Körb. Syst. Lich. Germ. 373), a graphic and appropriate term in reference to spores, which are 2-locular, with one division (upper) broader and shorter, and the other (lower) narrower and longer (as in *Abrothallus Smithii,* Tul. Linds. Monog. Abroth. plate iv. fig. 12).

my Herb.; exhibits sporiferous perithecia, cephalodia, and difform sterile tubercles and maculæ. The perithecia are scattered among the spermogones of the *Usnea*, and may be confounded therewith, or overlooked among them; but they are at once distinguished by the brown, 1-septate, figure-8 spores, which agree with those of *A. Usneæ*. The cephalodia resemble those in specimen No. 1 (var. *florida*), being generally difform-biatorine, or irregularly tuberculated, producing angularities of the branchlets. They occur also, however, as minute isolated papillæ or warts; sometimes becoming difform or maculæform; scattered on the ramules from base to apex of the plant; sometimes sub-terminal; generally producing angularities or deformities, like the larger more common forms—always more or less dark brown; and frequently assuming the aspect of species of *Celidium* or *Phacopsis*. These cephalodia are equally abundant and variable also in specimens of var. *ceratina* from Tasmania (LAWRENCE), and in *U. longissma* from Sikkim (Himalayas), both in Herb., Kew.

5. Var. *plicata*, Fr., Mauritius; in Herb., Kew; exhibits sporiferous maculæ and cephalodia, as variable in character as those described under No. 4. The maculæ are brown; they contain spores irregular as to size and form; always brown; sometimes simple and oval; sometimes 1-septate and figure-8-shaped; ·0004″ to ·0008″ long, and ·0002″ broad. The cephalodia are abundant, generally small, wart-like, resembling the apothecia of *Alectoria jubata*, Ach., producing, as usual, angularities of the ramules; occasionally having on their surface brown spores of the character of those of the parasite just described, and evidently referable to it.

6. Var. *ceratina* (*U. barbata*, Fr.), Hepp exs. 561. Some of the branchlets exhibit tuberculate, irregular, brown gouty swellings, resembling those produced by the spermogones on *Neuropogon melaxanthus*, Ach. and *N. Taylori*, Hook. fil. (Mem. Spermog. plate iv. figs. 9, 10, and 13, 14.) The parasite wholly surrounds the branchlet; is distinctly limited above and below; its brown colour is much heightened by moisture; it has no connection with any forms of either cephalodia or apothecia, but it exhibits no reproductive structure. The whole aspect of the parasite or deformity is Fungoid. In a specimen of *U. angulata* from New South Wales (also in Hepp's exs. 561), I find simple brown maculæ, which sometimes envelope the branchlet, sometimes colour its tip; but exhibiting no reproductive structure.

GENUS III. *Celidium*, Tul. Mém. Lich. p. 120; plate xiv. figs. 9–13; *Delisea*, Fée; *Plectocarpon*, Fée; *Dothidea*, Smrf. pr. p.; *Sphæria*, De Not. pr. p.

The essential character of the genus is the close aggregation of the sporiferous perithecia in round sori or maculæ (whence the generic name κηλιδιον, a macula), with central spermogones, as in *Phacopsis*. These sori or maculæ are blackish-brown; less or more raised above the thallus on which they are parasitic;

more or less irregular in their surface, though generally with a defined roundish form; immarginate; epithalline (not hypophlœod). Sometimes all—sometimes only the central perithecia—coalesce or become confluent—their apices only appearing and remaining somewhat free and distinct—forming the projecting prominences, which roughen the surface of the maculæ. The spermogones are spherical, simple, seated in the centre of the cluster of perithecia; spermatia straight, linear, very delicate, imbedded in hyaline mucilage. Pycnides have not been discovered.

Its species form parasites affecting the thallus and apothecia of various of the higher (foliaceous) lichens. The genus is variously regarded as a *Fungus** and *Lichen*,† whether by Lichenologists or Fungologists. Those who regard it as a *Lichen* class it usually among the *Lecideæ*,‡ though it appears to me, if it *is* to be considered a Lichen, to have at least an equal affinity to certain genera of the *Graphideæ* and *Verrucariæ*.

Sp. 1. *C. dubium* (figs. 47 to 52).

Parasitic on the thallus of various species of *Sticta*.

1. On *S. granulata*, Bab. (sterile specimen), Signal Hill, Dunedin; Dr Sinclair. The parasite affects generally the sterile, larger, and more granulose forms of the thallus, and seems most abundant towards the ends of the laciniæ. In what appears to be the young state of the plant, the perithecia are isolated and papillæform, with visible ostiola (figs. 47, 50 *a*); they gradually, however, become confluent, forming difform groups (*b*); and lastly, maculæform, exhibiting no distinct ostiola. Both papillæ and maculæ vary greatly in size; in both, the colour varies from deep umber to black (in the dry state). Both are raised more or less above the thalline surface; both are only partly or apparently sub-immersed by their bases. Interspersed among both occur much more minute, punctiform conceptacles, which may (when their normal contents are discovered) prove to be spermogones or pycnides (figs. 47, 50 *c*).

2. On *S. fossulata* Duf. (fructiferous and sterile specimens); corticolous (on trees), Saddlehill Bush.

In regard to site and external aspect, the parasite here has the characters described in No. 1. It is abundant on some specimens of the *Sticta* towards the tips of the laciniæ, to which it sometimes gives, even to the naked eye, a black-mottled appearance (fig. 49). There is the same transition from papillæ to maculæ (figs. 51–2), the latter apparently being always due to the confluence of the former. Here, however, the papillæ are more irregular in form, and the ostiole is never distinct. The maculæ are generally more or less raised or convex on their surface; and they are sometimes regularly spherical (figs. 49, 51 *a*), in which case they closely resemble the apothecia of certain *Arthoniæ* (e.g., *A. lurida* Ach). More generally, from the coalescence of several maculæ, or difform sori

* Nylander, Prod. 52. † Stizenberger, 163. ‡ *Ib.* 163.

of confluent perithecia, the plant forms most irregular blotches of a dark-brown colour (figs. 49, 52 *b*). The parasite can scarcely be confounded with the spermogones of the *Sticta*. The latter are confined to the thalline rugæ* (fig. 48 *b*), while the parasite is irregularly and generally scattered over fossæ and rugæ alike (fig. 48 *a*). The spermogones are, moreover, paler brown, wholly immersed, punctiform, and greatly more minute than the smallest or papillæform condition of the parasite. The latter occurs on the larger (sterile) darker-coloured, and more fossulate forms of thallus; while the spermogones are most distinct on paler and fertile forms. I have found similar parasitic perithecia or papillæ, isolated, variable as to size, but containing neither spores, spermatia, nor stylospores, in Tasmanian (and fertile) forms of *S. fossulata*, sent me by my friend M. C. Cooke.

3. On *S. rubella*, Hook. and Tayl. (sterile specimens), on trunks of dead trees, Greenisland Bush.

In some specimens of the *Sticta* the thallus is covered with blackish or brown blotches, apparently allied to the larger maculæ described in No. 2. But here they are not distinctly defined—the blotch gradually merging or fading into the beautiful red colour of the thallus. Nor are they distinctly raised above the thalline surface. Under the microscope, all the structure these blotches exhibit consists of a brown or blackish-brown filamentous tissue, composed of jointed cells, thick-walled, and varying much in length and breadth; whereas the perithecia, composing the maculæ in *S. granulata* and *S. fossulata*, though they exhibit no spores, possess a distinct envelope, consisting of small, irregular, dark-brown, closely packed cells; a structure which resembles that of the conceptacle of the parasitic *Microtheliæ* (figs. 26, 46).

It remains for the Local Botanist to determine whether it is the same parasite, which affects *S. granulata*, *S. fossulata*, and *S. rubella;* whether all the forms of Perithecia, Sori, and Maculæ above described, are referable to a single plant.†

Inasmuch as the parasite in all my Otago specimens was in an imperfect (infertile) condition for description and determination, it is necessary, in order to an approximate understanding of the nature and relations of the perithecia and maculæ referred to, to append some description of authentic and fertile conditions of the nearest European species. Of these, the most closely allied which I have seen appears to be—

4. *Celidium Pelvetii*, Hepp exs. 372 and 589. Parasitic on the thallus of *Sticta aurata*, Ach. (*S. aurata* var. *abortiva*, Schær.); Brazil; excellent specimens. The maculæ are so large and conspicuous, as well as so abundant, that the thallus is prominently black-mottled to the naked eye. Typical (fertile) maculæ are regularly round; convex or sub-conoid; isolated; of a deep blackish-brown colour; resembling in general aspect the apothecia of *Arthonia lurida*. In

* Lindsay, Mem. Spermog. p. 198, plate x. figs. 26–7.

† Compare *Sphæria homostegia*, Nyl.

the rudimentary condition (protothalline), they are flat, dendritiform maculæ; while, in the old state, from coalescence of sori, they also assume the condition of difform, flattened maculæ or blotches. At no stage of growth did I observe that division into separate, though agglomerated perithecia, which are described by TULASNE as characteristic of the genus; the surface of the sori is smoothish and uniform as in the apothecia of *Arthonia*. The maculæform condition frequently resembles various species of *Dothidea* (Fungi). Sometimes the maculæ, which are usually distinctly raised and epithalline, are sub-saccate, like the apothecia of *Solorina saccata*, Ach.; seated in a depression or pit of the thallus, and surrounded by an indistinct, raised, spurious thalline border. The maculæ vary greatly in size—the sterile rudimentary or degenerate, especially compound or confluent, ones being the larger. The latter especially have a decided Fungoid aspect. Fertile and sterile forms generally do not occur on the same thallus; hence, while spores are common and distinct in HEPP's exs. 589, they are with difficulty discovered or seen in No. 372. The hymenium, as examined especially in No. 589, whose constituents are extremely indistinct in the absence of any reagent, gives no blue reaction with iodine; but the paraphyses, which are closely aggregated and indistinct, acquire at their tips, which are naturally pale brown, a deep brownish red (Port wine) colour, or a violet red—sometimes very intense—which extends frequently to the thecæ and throughout the hymenium. The *thecæ* are 8-spored; short; sub-saccate; ·0018″ long, ·00045″ to ·0006″ broad; their protoplasm in the young state is very granular. The *spores* are solæform (1-septate), as in *Abrothallus Usneæ;* ·00045″ long, ·00022″ broad; but they are colourless or pale yellow. Under iodine, the epispore becomes more easily distinguished from the contained loculi, which are most distinct without the addition of any reagent, and which resemble somewhat those of the spores of various forms of *Verrucaria epidermidis*, Ach. The spores must be looked for in the youngish, or mature, regularly formed, spherical, convex sori. The same *Sticta* (*S. aurata*) in SCHÆRER's exs. 558, and in my Herb. from Rio Janeiro, PAUL, shows on its thallus a few irregular flattish maculæ, devoid of reproductive structure, and probably in their rudimentary or protothalline condition; apparently referable to *Celidium Pelvetii*.

5. *Celidium Stictarum*, Tul.; Mém. Lich. p. 121, plate i. fig. 17 *c*. and plate 14, figs. 5–8 (var. *pleurocarpa*, Ach., of *Sticta pulmonacea*, Ach.: "apothecia Fungosa abnormia"—of *S. pulmonacea*—Wallr. and Fr.; *Dothidea Lichenum*, Smrf.; *Sphæria Stictarum*, De Not.) Affects the apothecia (disk or epithecium) and the apotheciiform cephalodia of *Sticta pulmonacea*, Ach. NYLANDER refers the parasite to the *Fungi;* but points out its affinity to certain species of *Arthonia* (e.g. *A. varians*, Dav., and *A. Abrothallina*, Nyl., Prodr. 52, Syn. 352). The parasite covers the apothecia with an irregular black crust, which consists of considerable numbers of closely aggregated perithecia, sub-confluent, having in

the centre of the group the spermogones, which are small, spherical, frequently confluent; the walls thick and black; the spermatia straight, very slender, and about ·00012″ long.

A. NYLANDER exs. Covering the disk of the apothecia (the larger and more mature) of *Sticta pulmonacea*, Ach. *Thecæ*, pale blue or dirty purple with iodine; a fact of some significance in relation to the question, whether the genus *Celidium* is a *Lichen* or a *Fungus*; 8-spored; ·0023″ long, ·00066″ broad. *Spores* fusiform or ellipsoid; somewhat variable as to form and size; colourless; 3-septate; sometimes not exhibiting the epispore in the young state; sometimes seen in process of germination; in the old state brown and obscurely granular; ·00066″ long, ·00025″ to ·00016″ broad. Tips of paraphyses deep brown.

B. SCHÆRER exs. 550, sub nom. *B. pleurocarpa*, Ach, of *S. pulmonacea*, Ach. Here the paraphyses are extremely indistinct; the *thecæ* are 8-spored, and ·0020″ long, ·00066″ broad. *Spores* ·00083″ to ·00066″ long, ·00025″ broad; 3-septate; pale yellow; ellipsoid, sometimes sub-pyriform; sometimes exhibiting bulgings of the epispore opposite the septa.

Scattered irregularly over the thallus are numerous maculæ or papillæ of variable size and appearance, wholly devoid of reproductive structure, and evidently partly rudimentary or protothalline, partly degenerate; but apparently referable to the parasitic *Celidium*, whose sporiferous perithecia (perfect or fertile condition) are to be found only on the apothecia of the *Sticta*. The papillæ resemble young lecidiiform apothecia, or *Verrucariæ*, or spermogones. The maculæ are sometimes sufficiently raised or convex, and regular in their outline (spherical), to approach in character some forms of *Abrothallus* or certain lecidiiform *Arthoniæ*. Both papillæ and maculæ are blackish brown of various shades, and are isolated and somewhat regular in form, or confluent and difform; in the latter case frequently with ragged margin. The flat, thin (rudimentary) maculæ are sometimes irregularly stellate and Arthonioid; sometimes sub-dendritic; seldom confluent; sometimes elongated, or sub-oblong, and with a general Fungoid aspect; generally, with the other forms, seated on the thalline rugæ.

In HEPP'S exs. 590, the *Celidium* of the apothecia (of all sizes) of *S. pulmonacea* is accompanied with maculæ on the thallus, similar to those just described, and, as usual, without reproductive structure. Similar *Celidia*,* whether in their fertile and perfect—or, as is more generally the case, in their sterile and imperfect—state, occur on a large proportion of the *Stictæ*; sometimes on the apothecia or thallus, or both (as in *S. scrobiculata*, Ach, and *S. Freycinetii*, Del.); sometimes on the verrucose or tuberculose thalline cephalodia (as in *Ricasolia corrosa*, Ach. Nyl. Syn. 372): in which latter case the parasite is analogous to *Abrothallus*

* Yet apparently undescribed.

Usneæ on the cephalodia of *Usnea barbata*. In general terms it may be stated, that I have examined, with a view specially to the detection of this or other parasites, few species of the genera *Sticta*, *Stictina*, or *Ricasolia* (and especially belonging to the groups represented in this country by the types *Sticta pulmonacea*, *S. linita*, Ach., or *S. scrobiculata*, Ach., or in foreign countries by *S. fossulata*), without succeeding in finding some traces thereof.

The sterile or imperfect states of various *Celidia* are not distinguishable from each other, even on the most careful examination; without the *spores*, the species cannot be safely determined. The rudimentary or degenerate maculæ of *C. Stictarum* and *C. Pelvetii* are alike; but the spores are very different, regularly 3-septate and ellipsoid in the one, and equally regularly 1-septate and solæform in the other; while their site, also in the perfect or fertile condition, is generally diverse, being apothecia in the one case, and thallus in the other.

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*Explanation of Plates XXIX. XXX.**

PLATE XXIX.

Figs. 1–5. *Abrothallus Curreyi*, Linds.
1. Portion of thallus of *Parmelia perforata*, Ach.; nat. size; bearing
   a. Apothecia (of *Parmelia*).
   b. *A. Curreyi;* parasitic apothecia.
   c. Spermogones (of *Parmelia*).
2, 3. Diagrammatic sections (variously magnified) of
2. *A. Curreyi*, apothecia.
   a. Young.
   b. Mature.
3. Spermogones of Parmelia.
   a. Young.
   b. Old.
4. Section of hymenium of *A. Curreyi*, mag. 425 diam. linear.
   a. Epithecial membrane.
   b. Paraphyses.
   c. Thecæ.
   d. Hypothecial tissue.
5. Spores of *A. Curreyi*.

Fig. 6. *Abrothallus oxysporus*, Tul.
Spores; *a*. Young.
b. Mature.

Figs. 7, 8. *Lecidea Otagensis*, Nyl.
7. Section of hymenium.
   a. Paraphyses.
   b. Oil globules.
   c. Thecæ.
   d. Hypothecium.

Fig. 8. Spores; *a*. Young.
b. Mature.

Fig. 9. *Lecidea flavido-atra*, Nyl.
Spores; *a*. Young.
b. Mature.

Fig. 10. *L. melanotropa*, Nyl.
Spores; Mature.

Fig. 11. *L. amphitropa*, Nyl.
Spores; Mature.

Fig. 12. *L. coaretata*, Ach.
var. *exposita*, Nyl.
Spores; *a*. Young.
b. Mature.

Figs. 13, 14. *Lecanora homologa*, Nyl.
13. Section of hymenium.
   a. Paraphyses.
   b. Theca.
   c. Hypothecium.
14. Spores; *a*. Young.
b. Mature.
c. Old.

Fig. 15. *Lecanora peloleuca*, Nyl.
Spores; *a*. Young.
b. Mature.
c. Old.

Fig. 16. *L. thiomela*, Nyl.
Spores; *a*. Young.
b. Mature.
c. Old.
d. Do. in process of germination.

Fig. 17. *Placopsis perrugosa*, Nyl.
Spores; *a*. Young.
b. Mature.

* From the *colours* being *printed*, and not done by hand, the tints, in many cases at least, are more approximative than exact copies from Nature.

Fig. 18. *Opegrapha subeffigurans*, Nyl.
Spores; *a*. Young.
b. Mature.
c. Old, in process of germination.
Fig. 19. *O. agelæoides*, Nyl.
Spore; Mature.
Fig. 20. *O. spodopolia*, Nyl.
Spores; *a*. Young.
b. Mature.
Fig. 21. *Arthonia platygraphella*, Nyl.
a. Theca.
b. Spores.
Figs. 22, 23. *Platygrapha longifera*, Nyl.
22. Section of hymenium.
a. Paraphyses.
b. Theca.
c. Hypothecium.
23. Spores; *a*. Young.
b. Mature.
Figs. 24, 25. *Pertusaria perfida*, Nyl.
24. Section of hymenium.
ad. Paraphyses.
bc. Thecæ; *b*. to which iodine has been applied.
e. Hypothecium.
25. Spores; *a*. Young.
b. Mature.
Figs. 26, 27. *P. perrimosa*. Nyl.
26. Section of hymenium.
a. Paraphyses.
b. Thecæ.
c. Hypothecium.
27. Spores; *a*. Young.
b. Mature.
Fig. 28. *Pannaria immixta*, Nyl.
Spores; *a*. Young.
b. Mature.
c. Old.
Fig. 29. *P. gymnocheila*, Nyl.
Spores; *a*. Mature.
b. Old.
Figs. 30, 31. *Psoroma sphinctrinum*, Mut.
30. Spores; *a*. Mature.
b. Old.
31. Spermatia.
Fig. 32. *Physcia plinthiza*, Nyl.
Spores; *a*. Young.
b. Mature.
c. Old.
Fig. 33. *Ricasolia herbacea*, DN.
var. *adscripta*, Nyl.
Spores; Mature.
Figs. 34–36. *Sticta subcoriacea*, Nyl.
34. Section of hymenium.
a. Epithecial membrane.
b. Paraphyses.
c. Theca.
d. Hypothecium.
35. Spores in *Otago* specimens.
a. Young.
b. Mature.
c. Old.
36. Spores in Wellington specimens.
a. Young.
b. Mature.
c. Old.
Fig. 37. *Sticta filix*. Hffm.
a. Spores; young and mature.
var. *parvula*, Nyl.
b. Spores; mature.
Figs. 38–42. *Sticta damæcornis*, Ach.
var. *sub-caperata*, Nyl.
38. Portion of thallus; nat. size.
a. Apothecia.
b. Spermogones.
39. Same spermogones, considerably magnified.
40. Diagrammatic section of ditto, considerably magnified.
41. Spores; *a*. Mature.
b. Old, beginning to germinate.
42. *a*. Spermatia.
b. Sterigmata.

Plate XXX.

Figs. 1–7. *Sphæria Lindsayana*, Curr.
1. Portion of leaf of *Phormium tenax*, Forst., bearing the perithecia of the *Sphæria*; nat. size.
a. Larger, segregated forms of perithecia.
b. Smaller, crowded forms.
2. Perithecia; greatly magnified.
3, 4. Diagrammatic sections of ditto, greatly magnified.
5. Normal spores, magnified 425 d. l.
a. Young.
b. Mature.
c. Old.
6. Abortive spores.
7. Stylospores.
Figs. 8–15. *Sphæria Otagensis*, Linds.
8. Perithecia and spermogones, slightly mag.
9, 10, 11. Do. greatly mag.

12, 13. Diagrammatic sections of ditto.
14. Spores; *a*. Young.
b. Mature.
c. Old, in process of germination.
15. Sterigmata and spermatia.

Figs. 16, 17. *Patellaria atrata*, Fr.
16. Section of hymenium.
a. Theca.
b. Oil globules.
c. Paraphyses.
d. Hypothecium.
17. Spores; *a*. Young.
b. Mature.
c. Old.

Figs. 18–22. *Sphæria Martiniana*, Linds.
18. Perithecia; nat. size.
19. Do. magnified.
20. Diagrammatic section of ditto, considerably magnified.
21. Theca, with its spores.
22. Spores; *a*. Young.
b. Mature.
c. Old.

Figs. 23–28. *Microthelia perrugosaria*, Linds.
23. Portion of thallus of *Placopsis perrugosa*, Nyl.; showing its apothecia bearing the perithecia of the *Microthelia*; somewhat magnified.
24. Section of one of same apothecia; considerably magnified.
25, 26. Diagrammatic sections of apothecium of *Placopsis* and perithecia of *Microthelia* variously (but greatly) magnified.
27. Section of hymenium of *Microthelia*.
a. Paraphyses—Coloured by iodine.
b. Hypothecium.
cd. Two forms of thecæ.
28. Spores; *a*. Young.
b. Mature.

Figs. 29, 30. *Placopsis perrugosa*, Nyl.
29. Theca, with its spores—under iodine.
30. Spores; *a*. Young.
b. Mature.

Figs. 31–34. *Microthelia Cargilliana*, Linds.
31, 32. Apothecium of *Parmelia perforata*, Ach.; bearing the perithecia of the *Microthelia*; nat. size.
32. Section; *a*. the central perforation.
33. Diagrammatic section of same apothecium and perithecia; greatly magnified.
34. Spores; mature.

Fig. 35. *Parmelia perforata*, Ach.
Spores; *a*. Young.
b. Mature.

Figs. 36–41. *Phymatopsis dubia*, Linds.
36. An apothecium of *Usnea barbata*, Fr. var. *florida*, L.; bearing the parasitic spermogones; somewhat magnified.
37. Section of same apothecium.
38. Sterigmata and spermatia.
39. Portion of a branchlet of *U. barbata*, Fr. var. *ceratina*, Ach.; bearing the parasitic perithecia and maculæ; somewhat magnified.
40, 41. Sections of same branchlet maculæ (40), and perithecia (41).

Fig. 42. *Usnea barbata*, Fr. var. *ceratina*. Ach. Spores; discoloured and abnormal.

Fig. 43. *U. barbata*, Fr. var. *florida*, L.
Spores—normal; *a*. Young.
b. Mature.

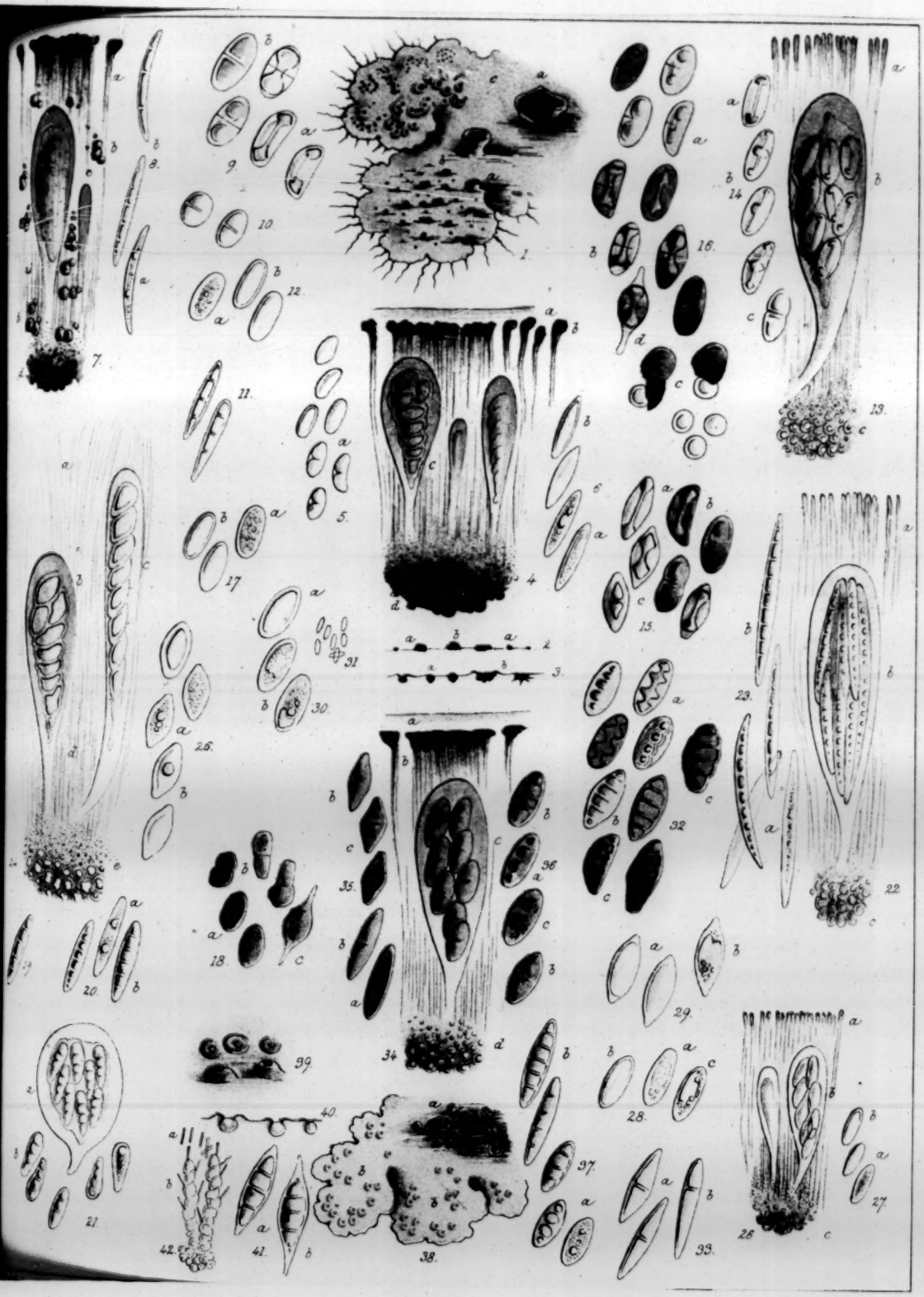
Figs. 44–46. *Microthelia Ramalinaria*, Linds.
44. Portion of a branchlet of *Ramalina calicaris*, Fr.; black-punctate, with the perithecia of the *Microthelia* (*b*); *a*. apothecium of the *Ramalina*; all somewhat magnified.
45. Section through the epidermis (cortical layer) of same branchlet, and through perithecia of the *Microthelia*; considerably magnified.
46. Section through one of same perithecia; greatly magnified.

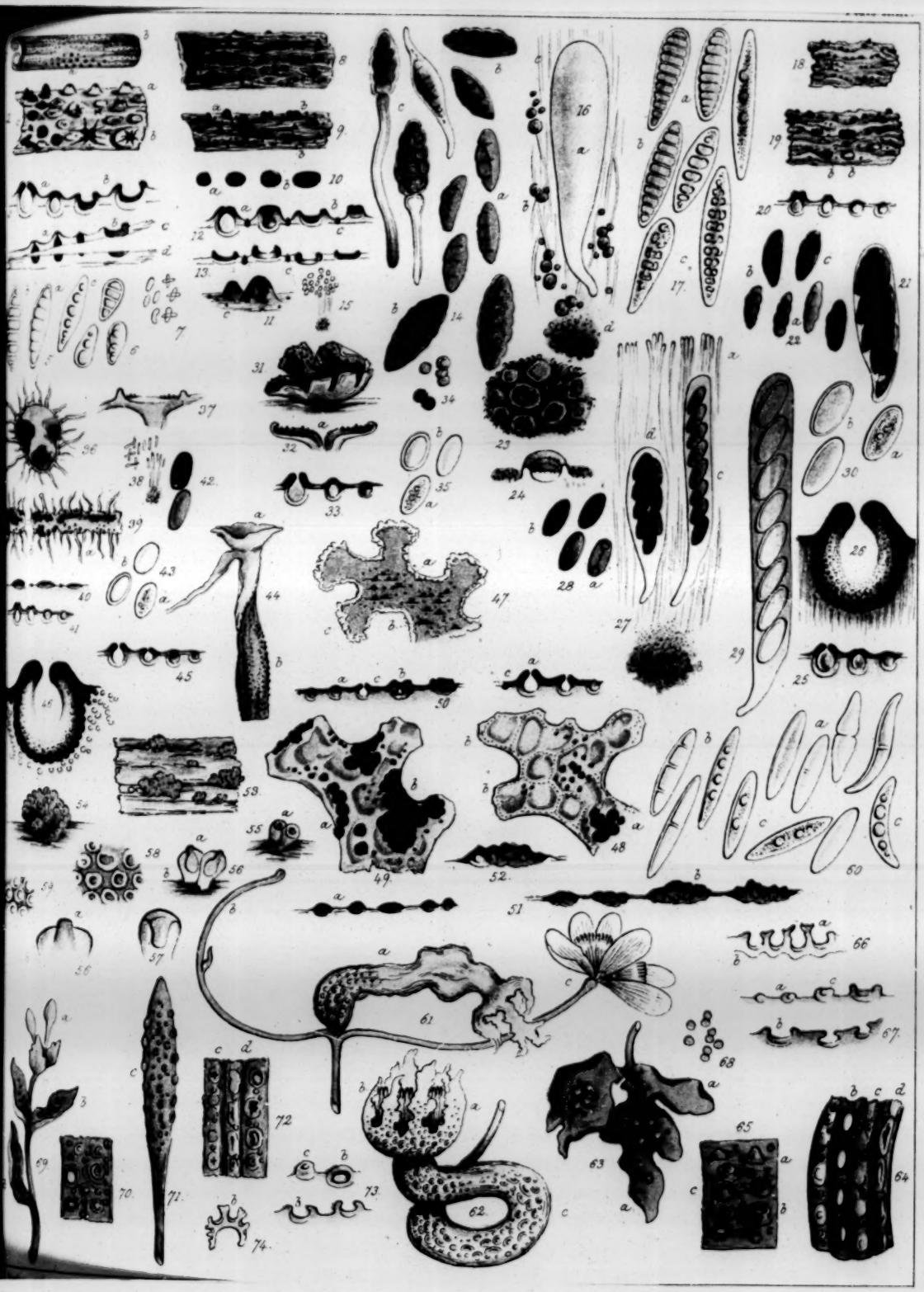
Figs. 47–52. *Celidium dubium*, Linds.
47–49. Portions of thallus (all somewhat magnified) of *Sticta granulata*, Bab. (47); *S. fossulata*, Duf. (48, 49).
48. More fossulate, brown form
49. Smoother, green form.
50–52. Sections of thallus of the *Stictæ* and of the parasitic maculæ and perithecia; all considerably magnified.
50. *S. granulata*, Bab.
51, 52. *S. fossulata*, Duf.

Figs. 53–60. *Nectria Otagensis*, Curr.
53. Agglomerated perithecia; nat. size.
54, 55. Do. more or less magnified.
56, 57. Sections of do., considerably magnified.
58. Perithecia; mature; viewed from above.
59. Do. old and empty; viewed from above.
60. Spores; *a*. Young.
b. Mature.
c. Old.

Figs. 61–74. *Æcidium Otagense*, Linds.
61–68. On *Clematis hexasepela*, DC.
69, 70. On *Epilobium junceum*, Forst.
71–74. On *Microseris Forsteri*, Hook. fil.

61. Less than nat. size.
    a. Flower and flower-stalk of *Clematis* affected by the parasitic *Æcidium*.
    bc. Normal flower and flower-stalks.
62. Nearly nat. size.
    a. Deformed perianth of *Clematis*.
    b. Normal anthers and stamina.
    c. Deformed flower-stalk.
63. Leaflet of *Clematis;* about nat. size; Peridia of *Æcidium*, somewhat magnified.
64, 65. Portions of flower-stalk (64), and leaf (65), of *Clematis*, with the parasitic peridia; considerably magnified.
66, 67. Sections of peridia of *Æcidium* in different stages of development; considerably magnified.
68. Spores of *Æcidium;* mature.
69. *Epilobium junceum;* bearing the parasitic peridia on its leaves; about nat. size.
70. Portion of one of the leaves of the *Epilobium*, with the peridia considerably magnified.
71. Leaf of *Microceris Forsteri;* bearing the peridia of *Æcidium;* about nat. size.
72. Portion of same leaf and peridia; considerably magnified.
73, 74. Diagrammatic sections of same peridia; considerably magnified.





XXXI.—*Description of* CALAMOICHTHYS, *a new Genus of Ganoid Fish from Old Calabar, Western Africa; forming an addition to the Family* POLYPTERINI. By JOHN ALEXANDER SMITH, M.D., F.R.C.P.E., F.R.S.E. (Plates XXXI. and XXXII.)

(Read 16th April 1866.)

In the beginning of the year 1865, I received from the Rev. ALEXANDER ROBB, one of the missionaries of the United Presbyterian Church, residing at Creek Town, Old Calabar, Western Africa, a package containing some zoological specimens, preserved in spirits; and in a letter dated 28th October 1864, referring to its contents, he states, there "are also two or three small eel-like fishes." Some time passed before I was able carefully to examine the package, and I was then at once attracted by these small fish, which I saw belonged to the very distinct and interesting Order of the Ganoid fishes, so abundant in a fossil state in the rocks of our earlier geological epochs, but of which so few representatives are now to be found as living inhabitants of the present waters of our globe.

The specimens of the fish sent were unfortunately very imperfect, the body of each having been torn across, apparently about the anal region, towards its caudal extremity, which was wanting; so that some of the characteristic details of the fish could not be ascertained.

The fish seemed to be closely allied to the genus *Polypterus*, first described in 1802 by Geoffroy-St-Hillaire. The genus *Polypterus* is believed to be the only living representative of a very ancient group of Ganoid fishes, included by Professor HUXLEY in his SUBORDER CROSSOPTERYGIDÆ, whose fossil remains are principally found in the Palæozoic rocks; and some of the Families of the group, to which, indeed, *Polypterus* seems most nearly allied, belong exclusively to rocks of the Old Red Sandstone or Devonian age.

I may remark in passing, that the true Ganoids (whose bodies are completely covered with Ganoid scales) of the present day, appear to be all inhabitants of the fresh waters of the globe. The various species of the genus *Polypterus* are found in the great rivers of the African Continent, and all the species of the other allied genera—those of *Lepidosteus* and *Amia*—inhabit the fresh waters of North and South America. While of the other Ganoids (whose bodies are only partially covered with ganoid scutes or plates), one genus, *Scaphirhynchus*, is found in the rivers of North America; and another, the genus *Accipenser*, the Sturgeon, inhabits the salt waters of the globe, and seems only at particular times to ascend the fresh waters or rivers. It would be an interesting subject

of inquiry to learn whether the different Orders and Genera of the Ganoids of the ancient world, those found fossil in our rocks, and taken cognisance of by the geologist, bore any similar relation to the rivers and their estuaries, and to the seas or salt waters of the Pre-Adamic earth. Judging of the past by the analogy of the present, it might almost be expected that the ancient Ganoids would bear a somewhat corresponding relation to the fresh and salt waters of their day, as is known to be the case with their living representatives in ours. Accordingly, it does certainly appear, in this country more especially, that numerous fossil remains of Ganoid fish have been found in formations that seem to point to a fluviatile, or at least an estuarine character and origin; and should there be any truth in the analogy, the presence of these fish would form a valuable additional element towards determining the character of any rock formation.

Only some six species of *Polypterus* have as yet been observed, and of these four belong, it is said, to the river system of the Nile; another to Senegal and proceeding still farther south along the western coast of Africa, we find a sixth species, which has been discovered in the rivers of Cape Palmas.

The specimens of fish sent from Old Calabar seemed, however, to differ considerably from all the species of the genus *Polypterus*, in various important characters to be afterwards detailed, and especially in the very elongated form of the body, and in the apparent total absence of ventral fins, which, however, from the imperfect state of the specimens, could not be conclusively determined.

While waiting, therefore, for more perfect specimens to settle definitely the question of the absence of the ventral fins, I exhibited the mutilated fish at a meeting of the Royal Physical Society, held on the 22d March 1865, and stated that all the species of the genus *Polypterus* seemed to bear a close resemblance to each other, in the general form of their comparatively short and fish-like body, and in the presence of ventral fins, forming thus a very natural group or genus. While the new fish, with its much elongated and more cylindrical form of body, and apparently the entire absence of ventral fins, suggested at least the probability of the existence, nearer the equator, of another allied but distinct group of these African fish. I would therefore place this fish provisionally in a new genus, which, from its general reptile or serpent-like aspect and form, I would designate *Erpetoichthys** (Ερπετὸν Ιχθύς)—the reptile or serpent-fish; and following the example of those Naturalists who have given the name of the locality where the fish was taken, to some of the species of *Polypterus*, I gave to this new fish the specific name of *E. calabaricus*.

I wrote to the Rev. Mr Robb, informing him of the very interesting nature of

* I have since learned that this designation, or a closely allied one, has been already used in Ichthyology, and accordingly, on the recommendation of Dr Gruntner of the British Museum, I have changed the name of the genus to Calamoichthys (Καλαμος a reed, and Ιχθύς, a fish), which will still bear a relation to the cylindrical character of the fish.—J. A. S.

the eel-like fish he had sent me, and requested him, if possible, to forward perfect specimens, so that its specific or generic differences might be determined and described; at the same time, I asked him to give me what information he might be able to gather as to its natural history. Since that time, accordingly, I have had letters from Old Calabar, and more recently, the perfect specimens of the fish now exhibited. Mr Robb writes from Creek Town, Old Calabar, that the fish is well known there, being occasionally sold in the markets, and eaten by the natives, though not by the most refined. It attains a considerable size, and is an inhabitant of the fresh waters of their brown, mud-laden rivers and creeks, through which, however, the tide flows for a great distance above Creek Town, where, indeed, at high water it rises to a height of seven feet, although Creek Town is some forty or fifty miles from the bar, at the mouth of the great river. The fish is essentially, Mr Robb says, a mud fish, and he considers it strange that he cannot get it in the dry season. It is caught during the rains, which last there from the beginning of June to the end of September. The fish is then to be found in the little fresh-water streamlets that run into the main rivers or creeks, and also in the pools in the marshy lands or mimbo swamps, as they are designated, from a kind of palm wine, or *mimbo*, made from some of the species of palm—the mimbo palms—which grow abundantly in such localities. The fish is most commonly found where the roots of the trees interlace together, and rise out of the water, leaving thus spaces below, through which the stream rises and falls with the ebb and flow of the tide. From the fact of the fish being only found at the season of the rains, it is not unlikely that they come at that time from the deeper parts of the river, to spawn in the shallows and streamlets; and this is also somewhat confirmed by the fact of the ova being abundant, and of considerable size, in some of the female specimens sent to me, which were opened for examination. The Rev. Mr Robb states that the fish sent are good specimens; two of them were brought to him alive in the fish-traps in which they were taken. This trap is a wicker basket, with an entrance made tapering inwards, like a funnel, so that if the fish once goes in, it cannot get out again. The traps are generally baited with a few palm nuts, and then sunk in the water. The natives have, however, many different ways of catching fish. Mr Robb kept the fish, thus caught, alive in water for several days, and noticed the snake-like agility and force of their movements.

Native name.—The fish is named by the natives *ú-nyang*, the literal meaning of which Mr Robb does not know, unless it may signify the struggler, or, to use a Scottish word as more descriptive of this supposed meaning—the "*wambler*." *Nyang-a* is a native verb signifying to struggle for a thing, as when two persons desire possession of one object; while *ú-nyang-a* is a scuffling or struggling for the possession of a thing. The name of the fish *ú-nyang* appears therefore to be a shortened form of the verbal noun; and was probably suggested by the twisting.

wriggling, or struggling movements of the fish, as it propels itself through the water or mud of the river.*

On examining the specimens of these fish, sent to me from Old Calabar, it was at once evident, from the total absence of ventral fins, that they entirely confirmed the view I had previously taken of their being new in character, and of the propriety of forming them into a genus distinct from that of the genus *Polypterus*.

Male and female different in appearance.—It was, however, also evident that the fish could be divided into two apparently distinct varieties, suggesting at first the idea that they might possibly be two species belonging to the same genus.

One having the body nearly equal in depth in its whole length towards the anal fin, with a distinct and well-developed anal fin and caudal extremity. While the other had a more tapering form of body posteriorly, and a very small anal fin, so small indeed, that when closed, and lying in its scaly groove, it might almost escape notice altogether.

On making a more careful examination, however, it was found that all the fishes of the first variety were males, and those of the second were females. The fact was therefore forced upon me, that this apparently strange and considerable variety in form was entirely sexual in its character, although somewhat the reverse of what we find in fishes generally,—the females being commonly distinguished from the males by the fuller and deeper form of their bodies,—and, as in all other respects the characters of both fish seemed to agree, that the fish were simply the male and female of the same species.

I also exhibit a specimen of the female of this fish, of larger size than the others, which was, with some other kinds of fish, politely sent to me from Africa, a few months ago, by Mr W. G. Mylne. These fish are stated to have been all collected by him in the district of the Great Camaroon mountains, on the coast of which the missionary station of Victoria has within the last few years been placed; this new ganoid, therefore, also inhabits the rivers of that still more southerly and little-known region, and, accordingly, this gives us an additional habitat for the fish.

I shall now give a detailed description of the fish, both of the male and female, and shall conclude with a summary of its characters, pointing out its general relations to, and differences from, the allied genus *Polypterus*.

* Mr Robb has recently sent me the following additional remarks on the native name of this fish:—"Many of the natives call this fish *Nyang;* and this suggests another possible etymology. *Nyang* is the stipule of the leaf of the mimbo palm, which, being of a narrow ribbon shape, dries up and remains twisted round the tree, from year to year, as long as the tree exists. The colour of the dried stipule is like that of the fish; and very possibly either the fish was named from *Nyang* of the mimbo palm, or *Nyang* was named from the fish. In this latter case, which is not at all improbable, the etymology is left undecided, and remains a matter of conjecture."

I. *Description of a Male* Calamoichthys calabaricus :—

Male.—A specimen measuring nearly 12½ inches in total length. (See Plate XXXI. figs. 1, 2, 3, 5, 6.)

Head.—The head is small, being less than one-twelfth of the total length of the body; depressed above, and rounded in front; it bulges out laterally, a little behind the orbits, and contracts again towards the back part, and the narrower neck of the fish. The front of the snout, sides of the head including the eye, and back to the opercular plate, are covered with a soft, smooth skin. On each side of the snout, in front, is a small projecting *tubular cirrus*, forming the *external nasal openings;* these cirri are about $\frac{1}{8}$ of an inch apart, and each measures $\frac{3}{20}$ of an inch in length; at the distance of $\frac{1}{8}$ of an inch behind them, and $\frac{1}{4}$ of an inch from the point of snout the *orbits* are situated, at the junction of the superior and lateral parts of the head. The orbital openings are small, measuring rather more than $\frac{1}{10}$ of an inch across; and from the back part of the orbit to the upper and posterior angle of the opercular plate, it measures $\frac{3}{8}$ of an inch in length.

A *series of bony plates* very similar in their arrangement to those of the genus *Polypterus*, commences a little behind the nostrils, and passing above the orbits, covers the whole upper portions of the head. These plates are arranged in pairs, one on each side of a nearly straight mesial line or suture; they are the exposed portions of the cranial bones, and are sculptured on their surface, like the scales of the body, and are also ganoid in their character. Beginning in front, a little behind the snout, there is, first, a pair of small rhomboidal-shaped plates, the *nasal bones;* these are rounded in outline in front, lie immediately on each side of the mesial line, and pass backward to the front of the orbits, where they are separated by a transverse wavy suture from the pair of plates immediately above and beyond them. The next plates are the *frontal bones*, the largest of the cranial plates; rather narrow in front, they become gradually broader at the back part of the orbit, and contract again in breadth as they proceed backwards, to meet, by a transverse suture in front of the spiracular openings, the next pair of plates, the *parietal bones;* which lie immediately behind them in the mesial line. The parietal bones or plates are somewhat quadrate in shape, but longer than broad; they are longer than the nasal plates, but are about a third shorter than the frontal bones, and they terminate posteriorly in a nearly straight transverse suture, which separates them from the small *supra occipital plates* or bones, two in number on each side of the mesial line, which cover the upper and back part of the head, at the nape of the neck. The *internal supra occipital plate*, that next the mesial line, is the longest and largest, being about a third longer than the external plate; it is somewhat rhomboidal in shape, and terminates in a rather rounded posterior extremity. The *external supra*

occipital plate is smaller in size, and somewhat triangular in shape, the straight base being in front, and the lateral margins terminating in a pointed posterior extremity. Between these supra occipital plates, laterally, and the smaller ossicles, to be afterwards noticed, which run along the sides of the head, there are other two small bony plates, on each side of the nape. One in front, the smaller, triangular in form, is the *epiotic plate* of Professor Huxley; it lies to the outside of the external supra occipital plate, and behind it lies the second, the *supra scapular plate*, somewhat larger, and more rhomboidal in shape, its longest diameter being outwards and backwards, it fills up the angular space behind the internal supra occipital plate, and the series of lateral ossicles; completing thus the covering of the upper and back part of the cranium. (Plate XXXI. fig. 6.)

In the mesial line, immediately behind and between the two internal supra occipital plates, lies the first of the true scales of the body on the dorsal surface, from which a row of scales passes the posterior margin of the supra scapular plate, and runs diagonally backwards and downwards along each side of the body.

The bony plates which cover the lateral and back parts of the head, consist, first, of a series of small ossicles, which commence a little behind the orbits, and run in a curved direction upwards and backwards, along the external margins of the frontal and other cranial plates, which have just been described, to the back part of the head. These small plates vary in shape from somewhat quadrate to triangular forms, and they also vary in number on the different sides of the head, being in this specimen ten on the one side and eleven on the other. Two of these small bones—which lie alongside the parietal bones, and behind the extremities of the transverse suture between them and the frontal bones, on each side of the head—have their inner margins free or unattached to the adjoining bones. This enables them to be raised up and opened, like a valve, which communicates with the branchial cavity. They have accordingly been styled the *spiracular ossicles*, which may be a sufficient designation for the whole series—those in front, between them, and the orbit, numbering some four or five bones, have, however, been named the *supra temporal ossicles;* and the plates placed behind these spiracular ossicles, are three or four in number, they continue the series along the upper margin of the operculum, and may therefore be styled the *supra opercular ossicles*. Outside and immediately below the supra temporal and spiracular ossicles the front of this series of small bones, and at a little distance behind the orbit, there is a larger, somewhat oval-shaped plate, the *preoperculum* of Agassiz, which runs backwards nearly to the line of the posterior margin of the parietal bones; and immediately behind it lies the still larger and broader *operculum*, an irregularly four-sided plate of bone, its anterior and superior margins being nearly straight, its posterior by far the shortest, and its lower and external margin much rounded in its outline. Below these plates the sides of the head are simply covered with soft and smooth skin, which expands into a free margin behind

the operculum, becoming much broader below, to join the back part of the jugular plates. (Plate XXXI. fig. 5.)

The branchiostegal membrane, between the rami of the lower jaw, is almost completely occupied by a pair of large flattened plates or rays—the *jugular plates*, as they have been named—the form of each being somewhat like a scalene triangle, with its acute point in front, and its longest side next the ramus of the jaw, the second lying parallel to the corresponding side of the other jugular plate, and the third or shortest and posterior side being somewhat rounded in its outline.

All the plates of the head, as well as the jugular plates, are sculptured, showing slight projections with rounded outlines, on their surface, which generally towards the margins of the plates assume an arrangement of concentric lines, and these lines commonly enclose a space in the centre, or towards one extremity of the plate, which is filled up with shorter and more irregularly arranged projections.

The *Mouth* is large. Its opening extends horizontally backwards beyond the back part of the orbit. The jaws are nearly equal in length, the upper projecting very slightly beyond the lower. The lips are full, and expand in a free membrane, from behind the nasal cirri, which becomes narrower towards the angle of the mouth; and again expands along the sides of the lower jaw. A series of strong, conical, and pointed *teeth*, sloping slightly backwards, extends along the edges of both upper and lower jaws; and immediately within this row, there is in the upper jaw a smooth furrow or groove, which seems to receive the teeth of the lower jaw when the mouth is closed. Beyond this groove in the upper jaw is a patch of villous-like teeth, which is broadest anteriorly ($\frac{1}{20}$ of an inch), and crescentic in shape, the horns projecting backwards; it covers the inner portion of the superior maxillary bones, continuing on to the palatines, the toothed surfaces becoming granular in character. The internal pterygoid plates, and the vomer in the centre of the roof of the mouth, are also all covered with granular teeth. Within the lower jaw anteriorly is a crescentic patch of granular teeth, which also measures $\frac{1}{20}$ of an inch across in front, and extends backwards in a line of teeth along the inside of the rami of the jaw; between this accessory group of teeth in front, there also runs a fainter smooth line or furrow, somewhat similar to that of the upper jaw.

The *Tongue* is full and rounded, and covered with papillæ, a deep fold or notch, on each side, partially divides it into two portions; and its base is covered with a patch of granular teeth.

Body.—The body is much elongated, its depth being about $\frac{1}{4}$ part of the total length of the fish; anguiform (cylindrical from behind the pectoral fins, to about the middle of its length a little behind the commencement of the dorsal finlets; it then becomes gradually more compressed in character (laterally), but remains

of nearly the same depth (vertically), tapering very slightly towards the anal fin, behind which it diminishes in depth to its caudal extremity). The caudal extremity is short, and tapers rapidly to a thin and conical point, around which the caudal fin-rays spring.

Scales.—The scales are osseous, and ganoid in character, and generally rhomboidal in shape; they are arranged in a regular series of rows, which cover the whole body. On the back each row begins in the median line, and runs obliquely downwards and backwards along both sides, until it terminates in the median line of the abdomen, and thus completes the circuit of the body. These rows are formed throughout of a single series of scales; in this specimen, however, there is a solitary exception to the rule, which occurs opposite to the commencement of the anal region, where two smaller and separate rows on the back run about half way down each side of the body, and then join in a single row below; this is the only exception to the rule which I have yet noticed.

The scales behind the head are small in size, and they gradually become larger as they proceed backwards over the body (where the rows of scales measure above $\frac{1}{10}$ of an inch across); they again, however, diminish in size over the caudal extremity of the fish. The scales also vary somewhat in size and shape in different parts of the same series, being slightly larger towards the lateral line of the body.

The general form of each scale is rhomboidal; a small tooth-like process projects forwards from the middle of its upper or anterior margin, and a lengthened lateral tubercle also projects outwards and forwards, from the inner and anterior angle of the scale. The anterior or upper edge of a scale, and one of its sides, the inner, that from which the projecting tubercle springs, are gently sloped or beveled, so as to pass slightly under the adjoining scales; its outer or free margin is nearly straight, and its posterior or lower margin is gently rounded in its outline. The under surface of each scale has a strong bar running down its centre; it begins anteriorly in the pointed process, or tooth of the scale, and posteriorly it divides into two branches, to accommodate the tooth, or anterior process, of the adjoining scale, which is laid in this space or socket, left at its posterior termination; the larger lateral process at the same time turning up along the under surface of the posterior and internal angle of the scale in front. The mesial scale of each series, on the dorsal surface, up at least to the first dorsal finlet, is oval in shape, the narrower anterior extremity being forked, having two anterior teeth lying side by side, which fix it to the connecting tissue and scales in front; and the longitudinal central bar on its under surface divides into two branches posteriorly, which run out laterally to the posterior edges of the scale, and each of these lateral terminations of the bar receives the tooth of the anterior or upper margins of the two adjoining scales—the first of the lateral series, and their tubercles lie along, and below its surface. The scales next in order, on

each side, have their anterior teeth laid in the forked terminations of the longitudinal bars of each of the scales in front and above them, their lateral tubercles being placed below the posterior and internal angles of these scales; and this arrangement is continued throughout the whole series, until we reach the mesial scale of the abdomen below, which is somewhat of a battledore shape, having a rounded body posteriorly, and a long projecting point, or handle, in front; about the junction of this handle to the body of the scale, are two small teeth-like processes projecting outwards and forwards, one on each side of the handle; and the scale is placed like a wedge between the adjoining scales, so that each tooth lies at the posterior extremity of the central bar of each of the scales in front of it; the series, or elongated loop of scales, which surrounds the body, being thus firmly and beautifully locked together and completed by the addition of the connecting tissue; so that it is no easy matter to separate one scale from another. The number of scales belonging to one of these loops or series is about thirty, or sixteen scales, including those of one side of the body only, and the median dorsal, and abdominal scales; the whole series, their free margins forming projecting lines, bend gently in an ogee-like manner, and run backwards and downwards across the sides of the fish, at an angle of about 45 degrees.

The scales generally are thin, especially towards their lateral and posterior margins, where they are almost semi-transparent or translucent, so that, when the specimen is moist in spirit, the toothed arrangement of the scales can be easily detected by the eye, and from the white colour of the fibrous attachments of the teeth and edges of the scales, a finely mottled character is given to the colour of the fish. These teeth-like processes appear to be present on most of the scales, until you reach the posterior parts of the body at its caudal extremity, where they seem to diminish considerably in size and in distinctness of character. (Plate XXXII. figs. 1–12.)

Beyond the origin of the first dorsal finlet, the oval-shaped scales in the dorsal mesial line are wanting, the bony spines of the finlets, as it were, taking their place; and the adjoining lateral scales on each side of the mesial line are laid together in a somewhat alternating manner; the sockets for the base of the osseous spines of each of the dorsal finlets being deeply cut out of the posterior margins of these scales, so as to give a shoulder or fixed support for the spine to lean against, when the finlet is raised up. (Figs. 13, 14.)

There are in all about 107 distinct rows of scales, between the nape of the neck and the extremity of the body; some 8 or 9 shorter series or rows being added in front, on the under surface of the body, to complete its scaly covering below, making altogether about 116 series of scales. Taking the number of the rows of scales (107) on the dorsal aspect; we find there are 50 series or rows between the nape of the neck and the scales forming the socket at the base of the spine of the first dorsal finlet; 8 series of scales lie between that and the

second dorsal spine; 6 between the second and third dorsal spines; 5 between the third and fourth; 6 between the fourth and fifth; 6 between the fifth and sixth; 6 between the sixth and seventh; 5 between the seventh and eighth; 5 between the eighth and ninth; 4 between the ninth and tenth; and 6 shorter rows between the tenth dorsal spine and the extremity of the body.

Microscopic character of scales.—The upper surface of each scale is shining, and sculptured in a manner somewhat similar to the plates of the head. Under the microscope the sculpturing of the scales shows numerous flattened disks, or projections of rounded outline, which are irregularly disposed towards the centre of its surface, but become more regularly arranged in a concentric manner towards its free margins; the anterior and internal beveled margins of the scale being nearly smooth. With a stronger microscopic power, the surface exhibits the raised and rounded portions alternating towards the margins, with intervening narrow and cylindrical-like projections, radiating outwards. The whole surface of the scale is found to be also covered with minute perforations or pores, apparently communicating with the cellular interior of the scale; while interspersed among these pores, there occur a smaller number of perforations or pores, of a larger size. (Fig. 6.)

I am indebted to my friend Mr CHARLES W. PEACH, the well-known naturalist, for the correct and careful drawings exhibited, which display these various details in the arrangement and structure of the scales. (See Plate XXXII.)

Lateral line.—The lateral line of the body is shown by a series of small mucous pores or openings, which appears in the scales (about the third, or fourth, from the mesial line of back), and runs in a line from behind the posterior angle of the operculum, to the middle of the caudal extremity. Occasionally, one or two scales in this line are apparently passed over, having no pores on their surface; and the series then goes on again after this interrupted manner; sometimes, however, the pores appear in the scales immediately over those in the line which appear to be passed over. Besides these pores, there are various others scattered apparently among the scales over the upper parts of the body of the fish, and occasionally even in the median scales of the back.

The fins.—The fins generally are small in proportion to the size of the fish.

The *Pectoral fins* arise immediately below the operculum, and are obtusely lobate in character, being connected to the body by a pedicle or arm-like process (as in *Polypterus*), which terminates in a gently curved distal extremity, from which the fin-rays spring, to form a rounded fin—the central rays being the longest. The base of the pedicle is covered on its external surface with small ganoid scales, apparently laid simply side by side, in rather irregular rows; these terminate in a nearly straight line across the middle of the pedicle, leaving an oval space bare, or free from scales, at the base of the fin-rays; the scales at the edges of the pedicle, however, pass backwards to the base of the fin-rays,

and a few are scattered along the base of the fin-rays themselves. The pedicle is smooth, having no scales on its inner surface, next the body of the fish. There is a roundish, dark, or black spot on the distal extremity of the pedicle, and partly also on the base of the fin-rays. The fin measures $\frac{1}{2}$ of an inch from the base of the pedicle to the extremity of its central fin-rays; the pedicle measuring $\frac{1}{8}$ of an inch, and the longest fin-rays $\frac{3}{10}$ of an inch in length. The breadth across the pedicle is nearly $\frac{3}{20}$ of an inch. The fin-rays are seventeen in number, and soft in character; they are, however, covered with single rows of very minute ganoid scales, which are placed, side by side, along the rays, and extend nearly to the membranous extremities of the fin-rays.

The *Dorsal finlets* are ten in number, and resemble in general character those of *Polypterus*, but they are each quite distinct and separate from the one next it. They commence about the middle of the fish, or a little behind it. In this specimen the first finlet lies at the distance of about $5\frac{5}{8}$ inches from the front of the snout; and the succeeding finlets are placed at short intervals from each other, backwards to the caudal extremity of the fish, the last being attached to the commencement of the fin-rays at the base of the tail. The intervals between the different dorsal finlets generally diminish gradually in this specimen as they proceed backwards towards the caudal extremity: thus the distance between the first and second finlets is $\frac{9}{10}$ of an inch; between the fourth and fifth finlets $\frac{7}{10}$ of an inch; and between the ninth and tenth finlets only $\frac{3}{10}$ of an inch.

Each finlet lies in a lengthened, somewhat triangularly-shaped, pit or longitudinal depression, which occupies the median line of the adjoining rows o scales, including one or two rows, and sometimes passes on to the third row of scales; and only about half, or even less, of this depression is occupied by the bony spine of the fin. When the fin is raised, the front of it is seen to be supported by this strong, bony ganoid spine, granulated or sculptured on its upper or anterior surface in a somewhat corresponding manner to the scales of the body, it is more sculptured in front, and becomes smoother towards the forked posterior extremity of the spine; the sharp points of the forks are nearly equal in length, the forked part occupying about a fourth or so of its length. A single soft fin-ray, springing from the root of the forked part of the spine, passes backwards to support the upper margin of each soft membranous fin. The last spine is attached to the base of the tail, and the ray is hard in character, and resembles those of the tail. When a finlet is closed, the soft ray and membrane lie in the longitudinal depression, and are covered and protected by the hard osseous spine which lies over them; its upper and sculptured ganoid surface being on a level with the rest of the dorsal surface of the fish. The spines vary slightly in length, being longest about the middle of the series of the finlets, and diminishing gradually towards each extremity; they measure about $\frac{3}{20}$ of an inch in length, the soft ray about $\frac{1}{10}$ of an inch, and the membranous finlet

along its base, including the thickness of the bony spine itself, about $\frac{3}{20}$ of an inch.

The *Ventral fins* are entirely wanting.

The *Anal fin* is placed immediately behind the anal opening, and close to the caudal extremity of the fish. Its base is marked by a loose flap or fold of the skin along each side of the body, which is covered by a distinct series of large oblong-shaped scales, some twelve or thirteen in number, laid side by side; and within this fold the closed fin lies as in a protecting case or sheath.

At the anterior part of the base of the fin there is a somewhat triangularly-shaped and thickened portion, the broad base of the triangle being next the body, and its point extending upwards in a fleshy or membranous skin, along the anterior margin of the fin; this triangular portion of the fin is covered by a group of scales, a patch of smaller ones in the middle, being surrounded by a row of larger scales outside.

The fin-rays are hard, and are thirteen in number; they consist of eight large, broad, and pointed rays, each closely covered with a row of ganoid scales; and of five smaller fin-rays posteriorly, more thinly covered with scales; and a membranous edge or border of the fin extends beyond the rows of small ganoid scales which cover each of the rays. You have, therefore, in this fin, first, the triangular base, with its extension alongside and in front of the fin-rays, then the group of eight large and strong fin-rays placed closely together, and completely covered with closely-set ganoid scales, the first ray being very large and broad; and next to this there is the group of slender, softer, and more separated or secondary rays, with their smaller rows of ganoid scales; the membranous extension of the rays forming a soft border to the fin all around. The length of the fin along its base is $\frac{2}{5}$ of an inch, and the length of its fifth or longest central fin-ray is also about $\frac{2}{5}$ of an inch; and its rays extend considerably beyond the base of the caudal fin-rays.

The *Caudal extremity* of the fish, from anus to extremity of caudal fin-rays, is $1\frac{1}{20}$ inch in length; it is therefore rather more than $\frac{1}{11}$ of the total length of the fish. It is much compressed laterally, and somewhat triangular in form; and the fin arising around its extremity is homocercal in character, at least in its general contour; the form of the tail being somewhat oval or rounded at its distal extremity; the fin-rays are large, strong, distinct, and covered with rows of ganoid scales; the anterior rays being shorter and somewhat fringe-like, especially above; those next the centre divide at about the middle of their length into two terminal rays, which again subdivide, and along which the ganoid scales are continued in a smaller series, to their distal extremities. The rays are all connected together by membrane, which is most distinct between the more separated rays at the commencement of the fin, on the dorsal surface of the caudal extremity. The fin-rays are thirteen or fourteen in number, the length of the

central rays, which spring from the termination of the vertebral axis, is $\frac{2}{5}$ of an inch, and the greatest breadth across the fin-rays is $\frac{2}{5}$ of an inch.

A sharp pointed style, or free bony process, covered with a continuation of the scales of the body, projects outwards for $\frac{1}{5}$ of an inch to the left side of the centre of the fin-rays of the tail; seven rays rising above, and six rays below, the line of its projection. This appears to be the termination of the vertebral column prolonged beyond the body, and lying among the fin-rays of the tail. It reminds one of a somewhat analogous but much greater extension of the vertebral column, prolonged, indeed, through the caudal rays altogether, and even bearing additional fin-rays of its own, which exists in various extinct fossil fishes. (Plate XXXI. fig. 3.)

The *Colour* of the fish is a uniform purplish brown above, shading off on the sides, and below, to a yellowish white; and the fish, when preserved in spirits, shows a faintly mottled appearance over the body, due to the whitish edges or lines at the junction of the scales shining through the adjoining scales.

The fins are like the body in colour, the scaly fin-rays being also dark, but the margins of the fins are generally lighter; the base of the pedicle of the pectoral fin is light in colour like the belly of the fish, and there is a black spot on its distal part, and at the base of its fin-rays, which are of a brown colour.

The measurements of this male fish are as follows:—

Length, or Longitudinal Measurements.

Total length, from point of snout to the extremity of caudal fin-rays, rather more than $12\frac{1}{4}$ inches.

Do. to caudal extremity of body, $11\frac{8}{10}$ inches.

Of head, above, from snout to commencement of scales of body, $\frac{1}{2}\frac{8}{0}$ of an inch.

Laterally, from tip of snout to superior and posterior angle of operculum, $\frac{1}{2}\frac{8}{0}$ of an inch.

From point of snout to base of first dorsal finlet, $5\frac{5}{8}$ inches.

From base of first dorsal finlet to extremity of caudal fin-rays, $6\frac{7}{8}$ inches.

From point of snout to anal opening, immediately in front of base of anal fin, $11\frac{1}{8}$ inches.

From anal openings to extremity of caudal fin-rays, $1\frac{1}{2}\frac{1}{0}$ inch.

Of central caudal fin-rays from extremity of body (not including style), $\frac{7}{2}\frac{7}{0}$ of an inch.

Breadth, or Transverse Measurements.

Of head across the widest part, over opercular plates, rather more than $\frac{1}{2}$ of an inch.

Of body behind the origin of the pectoral fins, $\frac{2}{5}$ of an inch.

Of body at the distance of one inch behind the pectoral fins, $\frac{11}{20}$ of an inch.

N.B.—The body continues of the same breadth onwards to beyond the first dorsal finlet, after which it gradually diminishes towards the caudal extremity.

Of body at the second dorsal finlet, about $\frac{1}{2}$ of an inch.

„ at the sixth dorsal finlet, about $\frac{7}{20}$ of an inch.

„ at the ninth dorsal finlet, about $\frac{3}{20}$ of an inch.

Of caudal extremity, $\frac{1}{10}$ of an inch.

Depth, or Perpendicular Measurements.

Of head, at pre-operculum, $\frac{7}{20}$ of an inch.

Of body, at the origin of pectoral fins, $\frac{9}{20}$ of an inch.

„ at the distance of one inch behind the pectoral fin-rays, $\frac{1}{2}$ of an inch.

„ at first dorsal finlets, $\frac{1}{2}$ of an inch.

„ at second dorsal finlets, $\frac{1}{2}$ of an inch.

„ at sixth dorsal finlets, about $\frac{1}{2}$ of an inch.

„ at ninth dorsal finlets, $\frac{9}{20}$ of an inch.

„ at posterior margin of anal fin, $\frac{1}{4}$ of an inch.

Greatest breadth across caudal fin-rays, $\frac{3}{5}$ of an inch.

Additional Specimens of the Male Fish, and Varieties in Character.

Six other specimens of the male fish were examined; they varied in length from about 8 to 10 inches. They also varied in some of their minor characters.

Dorsal finlets.—The dorsal finlets ranged from nine to eleven in number, and this variety occurred independently of the length of the fish; the longest fish not having necessarily the greatest number of dorsal finlets. They also differed, in the relation of the last dorsal finlet, to the caudal fin-rays; in some cases it was attached by its finlet to the base of these fin-rays, and in others it was quite distinct from them; and this last dorsal finlet had in some cases a hard fin-ray, like those of the tail, and in other cases a soft one, like those of the other dorsal fins. The dorsal finlets in these specimens varied also in their distance from one another; in some the distance between the finlets gradually diminished from before backwards, and in other specimens, again, the finlets at each extremity of the body were closer to one another than those occupying the middle of the range. When the finlets are more numerous, they rise nearer to the head of the fish than in those specimens in which they are fewer in number; thus, in a fish measuring $9\frac{4}{10}$ inches in length, with eleven dorsal finlets, the first one is at the distance of $3\frac{8}{10}$ from the point of thesnout. Any specific character of this fish, derived from the dorsal finlets, will therefore require to allow a considerable variety both in their number, their relations to one another, and also to the caudal extremity.

Scales.—The scales on the body are arranged in a series of single rows

regularly succeeding one another, over the whole body; the only exception I have noticed being in the large specimen already minutely described, and it is probably simply an individual peculiarity. In some specimens one or two of the mesial dorsal scales vary a little in form, being sometimes larger, and having a projection to the right, or to the left side, so as to include and cover the space commonly occupied by the first lateral scale. These occur irregularly along the mesial line, and sometimes one or two mesial scales are absent altogether.

Caudal fin.—The caudal fin also varied considerably in shape in different specimens, being much rounded at its extremity in some fishes, and in others rather acutely pointed. The fin-rays also appear to vary slightly in number.

No specimen, however, except the large one described, showed the projection of the termination of the caudal extremity of the vertebral column, in the form of a distinct style or process; but in some of the others there was noticed a fulness or thickness in the centre of the tail, where the prolongation may be covered and concealed by the scales at the base of the tail, and by the caudal fin-rays themselves.

Some of these peculiarities may be noticed a little more in detail in referring to these additional specimens of the fish :—

1. The first had only nine dorsal finlets, the last finlet with the hard fin-ray, as in the fish already described, being wanting.

2. The second, measuring $9\frac{1}{2}$ inches in length, the head $\frac{7}{8}$ of an inch, has the same peculiarity as the last, the finlets being nine in number.

3. The third has eleven dorsal finlets; the last is distinct, or not attached to the base of the caudal fin, and its small fin-ray is soft in character.

4. The fourth has also eleven dorsal finlets, the last finlet being also distinct, or separated from the caudal fin, and the fin-ray soft. It measures $9\frac{3}{8}$ inches in length, and the first dorsal finlet is $3\frac{4}{5}$ inches distant from the point of the snout.

5. The fifth has eleven dorsal finlets, the last is attached to the base of the caudal fin-rays, and its fin-ray is soft. It measures $9\frac{1}{4}$ inches in total length. The head measures laterally rather less than $\frac{3}{4}$ of an inch.

6. The sixth has ten dorsal finlets, the last being attached by its finlet to the base of the caudal fin-rays. It measures $8\frac{1}{4}$ inches in length, and the head laterally, rather less than $\frac{3}{4}$ of an inch.

7. The seventh has ten dorsal finlets, the last close to the base of the caudal fin-rays, and its ray soft. The tail is pointed.

8. The eighth has eleven dorsal finlets, the last being close to, but free from, the base of the caudal fin-rays, and the ray is soft. Tail rounded. It measures $9\frac{1}{2}$ inches in length.

9. The ninth has eleven dorsal finlets, the last attached to the base of the caudal fin-rays, and the ray hard. It measures $10\frac{1}{4}$ inches in length.

II. *Description of a Female* Calamoichthys calabaricus:—

Female.—A specimen, measuring 9½ inches in total length (including caudal fin-rays).

Head, like the male.

Body, relatively more slender and pointed posteriorly, towards its caudal extremity.

Fins.—Fins small:—

The *Dorsal finlets* like the male, but eleven in number, the last being attached to the base of the caudal fin-rays; each finlet has a single soft ray, with the exception of the last, which is hard, like the caudal fin-rays. The interval between these different finlets is widest in the middle of the series of the finlets:—thus, between the first and second finlets, it is ½ of an inch; between the fourth and fifth, rather more than ½; and between the ninth and tenth, it is only $\frac{3}{10}$ of an inch. The osseous forked spines supporting the front of each finlet are about $\frac{3}{20}$ of an inch in length.

The *Pectoral fins* are obtusely lobate, fin-rays seventeen, soft; length of pedicle and fin-rays about $\frac{3}{10}$ of an inch, of which the central fin-rays measure $\frac{3}{20}$ of an inch. The breadth across the pedicle is $\frac{1}{10}$ of an inch.

The *Ventral fins* are wanting.

The *Anal fin* is much diminished in size, as compared with that of the male, and when closed and laid between its scaly longitudinal folds of abdominal skin, it is scarcely perceptible. It is relatively smaller, and also more pointed in form, than that of the male, described at length. The triangularly-shaped group of scales at its base anteriorly is very small. The fin-rays are only eight in number; five of them being larger and more distinct, and covered with rows of small ganoid scales, and three rays being small and less distinct. Its rays extend only to the base of the caudal fin-rays, below; the length of the fifth or longest ray being ⅛ of an inch, and the breadth across the base of the fin is about ⅛ of an inch.

The *Caudal* fin is more acute or pointed; and the fin-rays are thirteen in number, and hard; the rays towards the centre of the tail being divided, and subdivided, as in the male.

The *Lateral line*, like the male, occasionally interrupted in its course, one scale, and then two or three scales, being passed over or having no pores. Various scattered pores also occur over the sides of the back.

The *Colour*, like that of the male.

The measurements of this female fish are as follows:—

Length, or Longitudinal Measurements.

Total length (including caudal fin-rays), nearly 9½ inches.

Do. of body—From point of snout to caudal extremity (not including fin-rays), 9⅛ inches.

Of head, above, from snout to commencement of scales of body, $\frac{12}{20}$ of an inch.

Laterally, from snout to upper and posterior angle of operculum, a little more than $\frac{14}{20}$ of an inch.

Eyes, rather less than $\frac{1}{10}$ of an inch across.

From point of snout to base of spine of first dorsal finlet, $4\frac{1}{5}$ inches.

From spine of first dorsal finlet to extremity of caudal fin-rays, $5\frac{3}{10}$ inches.

From point of snout to anal openings, $8\frac{11}{20}$ inches.

From anal openings to extremity of body (not including caudal fin-rays), $\frac{12}{20}$ of an inch.

From anal openings to extremity of caudal fin-rays $\frac{18}{20}$ of an inch.

From extremity of body to extremity of caudal fin-rays, $\frac{3}{10}$ of an inch.

Breadth, or Transverse Measurements.

Of head, across operculum, about $\frac{2}{5}$ of an inch.

Of body, behind origin of pedicles of pectoral fin, $\frac{3}{10}$ of an inch; the body then increases rapidly in breadth, and at the distance of one inch behind the pectoral fins, measures about $\frac{2}{5}$ of an inch.

„ at the first dorsal finlet, $\frac{2}{5}$ of an inch.

„ at the second, $\frac{7}{20}$ of an inch.

„ at the sixth, $\frac{1}{4}$ of an inch.

„ at the ninth, $\frac{3}{20}$ of an inch.

„ at the caudal extremity of the body, immediately behind the anal fin, rather less than $\frac{1}{10}$ of an inch.

Depth, or Vertical Measurements.

Of head, over pre-operculum, $\frac{1}{4}$ of an inch.

Of body, opposite the origin of the pectoral fins, $\frac{3}{10}$ of an inch.

„ at the distance of one inch behind the pectoral fins, $\frac{7}{20}$ of an inch.

„ at the first dorsal finlet, $\frac{7}{20}$ of an inch.

„ at the second dorsal finlet, rather less than $\frac{7}{20}$ of an inch.

„ at the sixth, about $\frac{7}{20}$ of an inch.

„ at the tenth, rather less than $\frac{3}{10}$ of an inch.

„ at the caudal extremity of the body, immediately behind the anal fin, $\frac{1}{5}$ of an inch.

Additional Specimens of the Female Fish, and Varieties in Character.

Several additional specimens of the female fish were also examined; and similar varieties in the minuter details of their characters were found to exist among them, as in the males. Some small range was found to exist in the relative proportions of the head and the body.

Scales.—The series of scales over the fish were generally in regular single

rows on all the specimens. Varieties in the mesial dorsal scales were noticed, similar to those in the males.

Dorsal finlets.—Varieties in the number of the dorsal finlets also occurred. These seemed to range from nine to eleven in number, and to be irrespective of the size or total length of the specimen, the longest and largest specimen having, indeed, the fewest dorsal finlets. The relation of the last finlet to the base of the tail and the caudal fin-rays seemed also to vary, as well as the softness or hardness of its accompanying fin-ray. The relative distance between the different individual dorsal finlets also varied in the different specimens.

Anal fin.—The anal fin in all the specimens was similar in character to the one described.

Caudal fin.—The caudal fin was rounded in its outline in some of the specimens, and more acute and pointed in others, so that in this also some range of shape must be allowed.

The *Colour*, or shade of colour, was like that of the male, but varied in the different specimens to a considerable degree, the darker colour of the back extending considerably over the sides of some of the specimens, and leaving only a small portion of the abdomen of a lighter or white colour; while in others, the colour was lighter on the middle of the sides of the body, and the abdomen of the fish was nearly white.

I add a few notes of some of these female specimens examined:—

1. The first had ten dorsal finlets, and the tenth had its fin-ray soft, and the fin attached to the base of the caudal fin-rays.

2. The second measured $8\frac{3}{4}$ inches in length, the head measuring laterally nearly $\frac{3}{4}$ of an inch; dorsal finlets ten in number, the tenth distinct and separate from the caudal fin-rays, and its fin-ray soft.

3. The third measured $8\frac{1}{16}$ inches in length; dorsal finlets ten in number, the last not connected to the caudal fin-rays; and the secondary ray of the last finlet soft.

4. The fourth was of a larger size than the others, measuring 11 inches in length. It was sent to me, as already stated, by Mr W. Grant Mylne, from the district of the Camaroons, Western Africa. Dorsal finlets only nine in number, the ninth being distinct from the caudal fin-rays, and its fin-ray soft. The first dorsal finlet is $5\frac{3}{8}$ inches distant from the point of the snout, and from the first dorsal fin it measures $5\frac{3}{8}$ inches to the extremity of the rather pointed caudal fin. (Plate XXXI. fig. 4.)

Food of the Calamoichthys calabaricus.

Termitidæ.—Various specimens of perfect insects and larvæ were taken from the stomach of one of the female fishes. These fish are, therefore, as might have been expected, carnivorous and insect-feeders; in anglers' phrase, they take the

fly; and although some of them were caught in fish traps, which are stated to have been baited with palm nuts, it must have been simply from curiosity that the fish poked into them, and were taken; or perhaps the palm nuts might attract insects and their larvæ, in the water, and the fish, following in pursuit, be in this way decoyed into the trap, and captured.

The insects found in the stomach of the fish belonged, as far as was noticed—for the more perfectly preserved insects alone were examined—to the abundant African family of the *Termitidæ*, the Termites, or white ants, as they have been designated. These insects were found under all their stages or transformations.

1. Eighteen specimens of *labourers* or *larvæ* were collected. These measured each $\frac{1}{8}$ of an inch in length. The head is whitish, but the jaws are tipped with blackish or brown colour, and are horn-like in their appearance. The thorax and legs are white; the abdomen is rounded, the dark-coloured viscera or their contents shining through the white and semi-transparent skin. No eyes were visible.

2. One specimen only of a *soldier* Termite was seen; it was $\frac{3}{10}$ of an inch in length. The body is white, but the contained viscera show black, like the last, through its semi-transparent skin. The thorax is white. The head is large, square in front, and rounded behind; it is larger in size than the abdomen, and is reddish in colour especially in front, and horny-like in structure, with two black scimitar-like projecting jaws. No eyes were visible.

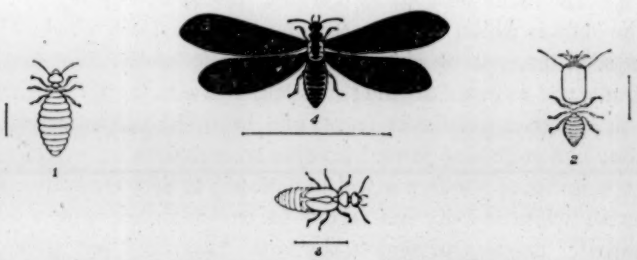
3. Six specimens of *pupæ* were also noticed; their bodies are entirely of a pale yellowish white colour, and seem to be of rather a soft consistence; the eyes, however, are now present in the form of minute black specks, distinctly visible. The abdomen is large and full. Four flattened lobes—the projecting wings—pass backwards from the thorax; they are very distinct, but do not extend backwards as far as the posterior extremity of the body, the wings being apparently folded upon themselves from below upwards, at about the middle of their length. The pupæ measure each about $\frac{7}{20}$ of an inch in length.

4. Five-winged and *perfect insects*, or *Termites*, were examined. Their bodies are generally dark-brown in colour, with four long narrow and blackish-coloured semi-transparent wings, nearly equal in length, with black nervures, the costal and sub-costal are robust and unbranched, the other nervures being finer, and branching over the rest of the wing. (In the specimen figured below, the nerve next the subcostal varies in the arrangement of its branches in each of the upper wings, probably an accidental peculiarity.) The wings extend considerably ($\frac{6}{20}$ of an inch) beyond the body, the total length of the insect to the extremities of the wings being $\frac{11}{20}$ of an inch, and that of the entire body $\frac{1}{4}$. The head and upper parts of the thorax are dark-brown, the legs lighter; the stemmata are immediately in front of, and slightly below, the eye on each side, and a little in front and above the origin of the antennæ, and no central point was observed; the abdomen on its upper surface has ten segments or plates of a dark colour

showing intervening spaces of white skin in some specimens, and these bands are separated on each side, from those of a similar character on the under surface of the abdomen, by a longitudinal space of white skin, which extends along the whole length of the abdomen. This arrangement allows for the wonderful expansion and development of the abdomen in the gravid female. The plates on the under surface of the abdomen are white in the middle of each plate, and become blackish only towards their extremities.

The antennæ in all these different creatures are moniliform and rather short, consisting apparently of fourteen small, rounded, dark-coloured, and hairy joints or divisions; they are paler in the soldier, and nearly white in the pupæ.

The presence of these various insects, in the different stages of their transformation, found in the stomach of the fish at the same time, is interesting as showing that numbers of them must undergo these changes, at different periods of time or in succession, in the same nest.



TERMITES from the stomach of the *Calamoichthys calabaricus*, Old Calabar River.—1. The Labourer; 2. The Soldier; 3. The Pupa; 4. The Perfect Insect.

The Termites, it has been said, furnish a regular supply of delicious food not only to other insects, to reptiles, to birds and beasts, and even to man himself, who eats the perfect insects at least, of a larger species than the one just described; but the finny tribes, as represented by our ganoid, seem also to come in for a share of these savoury and most abundant insects.

It is easy to understand how the winged flies should become the prey of fish, as vast quantities of them are said at certain seasons of the year, as at the beginning of the rains, to be spread over the whole face both of the land and water; but it is not quite so easy to see how the other wingless and less perfectly developed insects should come within the range of the feeding-grounds of the fish. Either their under-ground galleries, which spread out in every direction from their wonderfully-constructed castles, may have been accidentally broken open at the river's banks, and their teeming population poured forth; or more probably, the heavy tropical rains may have washed them from their broken galleries into the river's bed.

I took these specimens of Termites to the British Museum, but was not

able to learn if the species was new, as the gentleman who has the charge of that particular department was unfortunately absent in bad health. They appeared, however, to resemble a species from Sierra Leone, unnamed in the collection; and the presence of the so-called pupæ, is probably somewhat of a rarity, at least none were noticed among the specimens exhibited in the cases.

I am indebted to Mr R. F. Logan, Duddingston, who fortunately combines in himself the entomologist and the artist, for the annexed very correct drawings of these insects, which will, I hope, enable those more intimately acquainted with the *Termitidæ* to determine their species.

A small and partially digested crustacean, of the prawn kind, was the only other creature observed in the stomachs of these fishes.

General Summary of the Genus Calamoichthys, *and its relation to the Genus* Polypterus.

Genus Calamoichthys.—*Head*, small, depressed above, somewhat oval in shape (rounded and narrow in front, expands laterally behind orbits, and contracts again at the back part towards neck); sub-operculum wanting (no small plates below pre-operculum).

Body, much elongated, anguiform (cylindrical for about half its length, then becoming gradually more compressed laterally, and tapering very slightly towards its caudal extremity). *Caudal extremity*, short, tapering rapidly. *Caudal fin*, rounded; homocercal in its general contour; fin-rays, hard. (*Scales*, osseous, rhombic, sculptured; becoming somewhat larger in size as you proceed backwards along the body, and again smaller on the caudal extremity.)

Fins, small:—*Pectorals*, obtusely lobate; fin-rays, soft. *Dorsal finlets*, numerous, separate. *Anal*, in male, large; in female, small; fin-rays, hard. *Ventrals*, wanting.

The last character is rather an important one, as this fish thus appears to be the only living ganoid yet known which has no ventral fins. Van der Hoeven, in his valuable "Handbook of Zoology," gives the presence of ventral fins as one of the characters of his great Section III. of the Class Pisces, the *Ganoidei*, or, as he terms them, the *Ganolepidoti*. He says they have "pectoral and ventral fins, the ventrals placed behind the pectorals." While older naturalists, as Cuvier, from the supposed constant presence of ventral fins, have placed the ganoids in the Order of Malacopterygii abdominales. The discovery of this new fish will, therefore, necessitate a change in this character of the whole section.

In the Genus Polypterus (on the other hand), the *Head* is relatively larger (with apparently little or no lateral expansion, and subsequent contraction towards its neck); its gently swelling outlines gradually expand, and run backwards into the tapering outlines of the body. Sub-operculum present; several small plates below pre-operculum.

Body, relatively much shorter, generally tapering gradually from behind the

region of pectoral fins, and becoming more compressed laterally, and tapering slightly towards its caudal extremity. *Caudal extremity*, longer. (*Scales* generally smooth [?])

Fins, larger:—*Pectorals*, fin-rays osseous. *Anal*, apparently alike in size in male and female. *Ventrals*, present.

This new ganoid fish, from the great elongation of its body and the shortness of its caudal extremity, must swim in a manner somewhat different from the fishes of the genus *Polypterus*, and still more from that of ordinary fishes, whose progression is due to alternate strokes or sweeps of the caudal extremity; whereas in this fish, assisted by its very large and long swimming or air bladders, it must be accomplished, as in eels and serpents, almost entirely by alternate and successive lateral undulations of the whole body; and the peculiar character of its scales, which are comparatively small anteriorly, and enlarge posteriorly, the posterior margin of each series of scales being free and projecting, would also seem to assist in giving greater flexibility and force to these movements.

The genus *Calamoichthys* agrees with the genus *Polypterus*, in the general character of its numerous dorsal finlets; lobate pectorals; two nasal cirri; a spiracle, or valve-like opening on each side of the head above, and a large flat branchiostegal ray, or jugular plate, on each side of the mesial line below; and also in the hard, osseous, rhomboidal-shaped ganoid scales, arranged in rows, running obliquely downwards and backwards; and in the tapering caudal extremity of the body.

It differs from *Polypterus*, however, in the various distinct peculiarities which I have already enumerated, and especially in the great elongation of its body and the total absence of ventral fins; and these appear to be fully sufficient to justify and confirm the propriety of its being placed in a distinct and separate genus, to which, from the general lengthened and cylindrical form of the fish, I have given the designation of *Calamoichthys*—(Καλαμος and ιχθύς). The new genus belongs, therefore, to the same family as *Polypterus*, and would accordingly fall to be placed next to the genus *Polypterus*, in the family of the *Polypterini*.

FAMILY POLYPTERINI.

I. Genus POLYPTERUS. II. Genus CALAMOICHTHYS.

1. Species *C. calabaricus*.

Habitat, Old Calabar river, and the Bimbia, Camaroons, Western Africa.

For the purpose of getting an anatomical description of this new fish, I placed specimens, both of the males and the females, in the hands of Dr Ramsay H. Traquair, Junior Demonstrator of Anatomy in the University, who has, accordingly, prepared a detailed account of its anatomy.*

* An abstract of Dr Traquair's paper is published in the Proceedings of the Royal Society of Edinburgh, vol. v. p. 657.

Description of Plates XXXI., XXXII.

Plate XXXI.

Calamoichthys calabaricus.

Fig. 1. Male, dorsal view (natural size).
Fig. 2. Do. lateral view „
Fig. 3. Caudal extremity of Male (double the size of specimen).
Fig. 4. Do. of Female „ „
Fig. 5. Head of Male, lateral view (four times the size of specimen).
Fig. 6. Do. dorsal view „ „

N.B.—Unfortunately the anal and caudal fins, &c., and their fin-rays, have not been drawn with a very minute attention to details.

Plate XXXII.

Scales of Calamoichthys calabaricus.

Fig. 1. A series of scales, from the lateral surface of the fish, including a mesial dorsal (*c*), and ventral scale (*b*). The mucous pore is shown at *a*.
Fig. 2. Portion of three adjoining rows of scales, external surface.
Fig. 3. Internal surface of the same scales, showing the manner in which they are locked together.
Fig. 4. A single scale from the middle part of the fish, showing the tooth and internal tubercle, and the sculpture on its external surface.
Fig. 5. Internal surface of the same scale, with the longitudinal bar along the back and the socket at its posterior termination, for receiving the tooth of the adjoining scale.
Fig. 6. Highly magnified view of part of the sculptured or external surface of the same scale.
Fig. 7. One of the median dorsal scales; its outer or external surface.
Fig. 8. Lower or internal surface of ditto.
Fig. 9. One of the median ventral scales; its outer surface.
Fig. 10. Inner surface of ditto.
Fig. 11. External surface of scale from posterior part of body, near the anal region, showing gradual alteration in form.
Fig. 12. Internal surface of ditto.
Fig. 13. First dorsal finlet, showing the forked spine of the finlet, and the general arrangement of the scales around it; seen from above.
Fig. 14. Lateral view of ditto; the spine of the first dorsal finlet, being partially raised, showing its secondary ray and finlet (from male fish described).

N.B.—All these figures are more or less magnified.

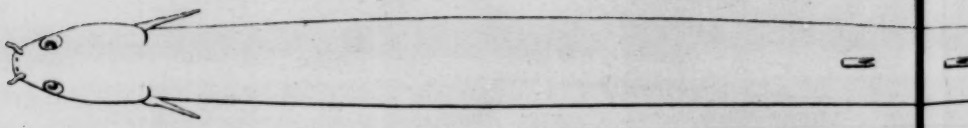
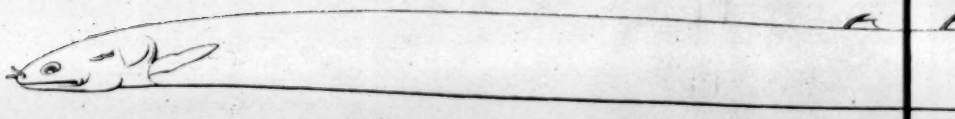
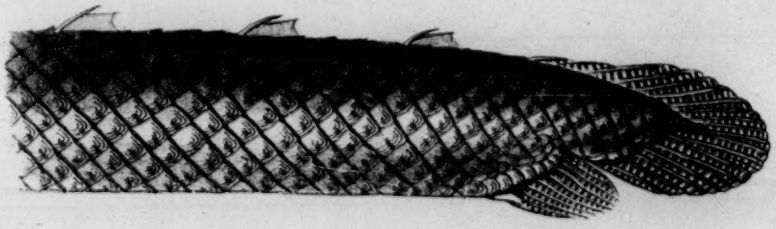


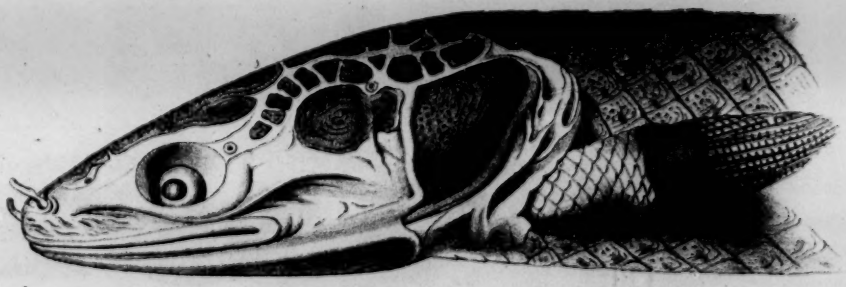
Fig. 1.



2.



3.



5.

N. Stewart ad. nat. del.t

CALAMOICHTHYS CALABA

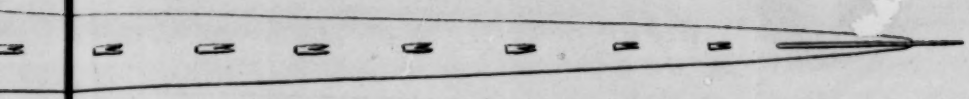
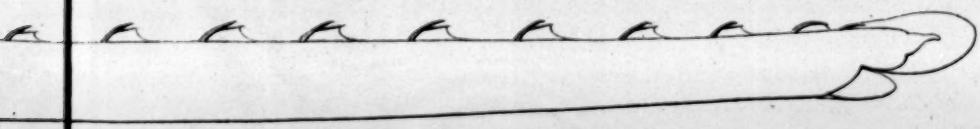
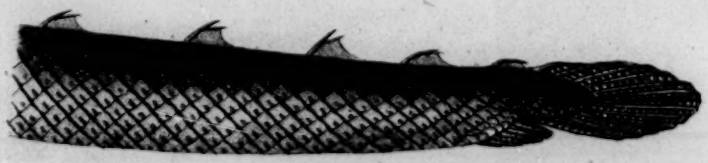


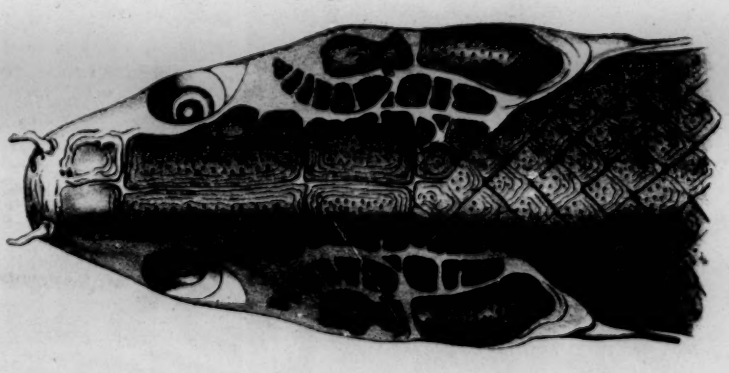
Fig. 1.



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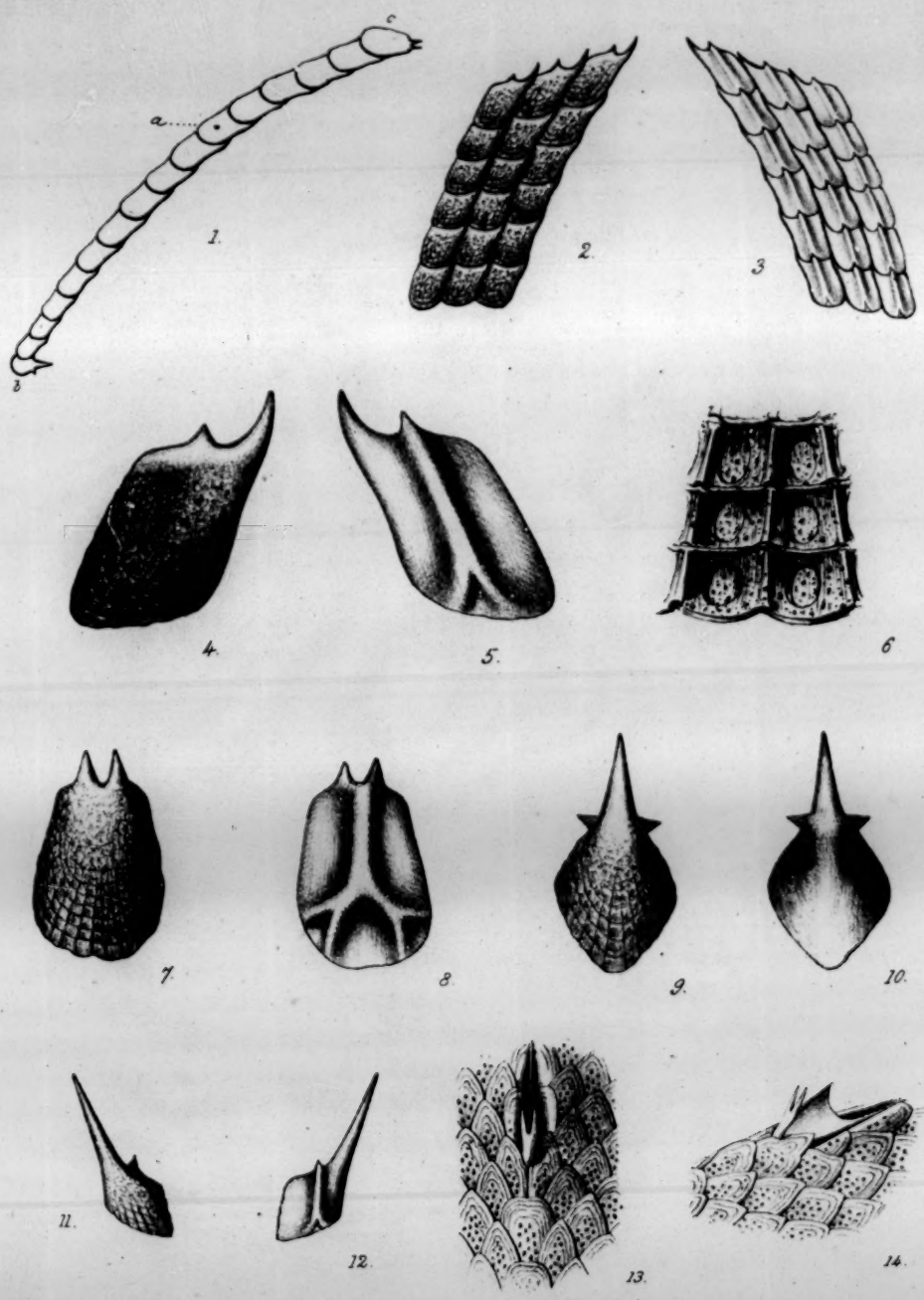
4.



6.

HYS CALABARICUS (J. A. SMITH.)

W.H. M^c Farlane, Lith^r Edin^r



C.W. Peach del.r

W.H. M.c Farlane Lith.r Edin.r

Scales of Calamoichthys calabaricus. (J.A. SMITH)

XXXII.—*Note on Formulæ representing the Fecundity and Fertility of Women.* By Professor Tait.

(Received Oct. 1, 1866, and ordered by the Council to be inserted as an Appendix to Dr Duncan's papers in Vol. XXIII., and in the present volume, of the Transactions.)

1. Dr Matthews Duncan having requested me to point out to him some simple method of comparing the fertility of different races, I endeavoured, as a preliminary step, to represent by formulæ some of the chief results which he has obtained in his very lucid and elaborate papers recently read to this Society, and printed in their Transactions for 1863–4 and for the present session. Some of the formulæ which I have obtained are so simple, and accord so well with the tables, that I have thought them worth bringing before the Society. Of course it must be understood that I advocate no theory, and pretend to no physiological knowledge of the question. I merely try to represent, in a simple analytical form, the contents of some of Dr Duncan's tables.

2. To prevent misconception, let us begin by defining the terms *fecundity* and *fertility* as they will be used in this note, unless qualified in some manner.

By *fecundity* at a given age we mean the probability that during the lapse of one year of married life, at that age, pregnancy, producing a living child, will ensue. This is, in all likelihood, modified in each individual woman by the previous duration of marriage (see § 10 below). But at present, in dealing with the mass of wives, we omit this consideration. We do not require, in our calculations, to consider any questions connected with the duration of life of husband and wife, of the length of time the child may live, &c., as the numbers in the tables are already influenced by such causes. The numbers in the tables do not usually denote the fecundity as above defined, but are quantities proportional to its values.

By *fertility*, at any age, we mean the number of children which a married woman of that age is likely to have during the rest of her life, or some numerical multiple of it.

The subject divides itself into three heads—(I.) The fertility and fecundity of the mass of wives; (II.) their value for the average individual; (III.) the *relative* fertility and fecundity of different races.

These we proceed to consider in order.

I. *Fertility and Fecundity of the Mass of Wives.*

3. If f_t represent the fecundity, and F_t the fertility at the age of t years,

the ordinary laws of probability, if applicable to this question, give us the expression—

$$F_t = f_t + f_{t+1} + \ldots + f_{50} = \Sigma_t^{50} f_t$$

assuming that sterility arrives about the age of fifty.

Before going further, it may be well to verify this formula by comparison with the tables, so that we may be assured of the validity of our reasoning.

Dr DUNCAN gives (*Trans. R. S. E.* 1863–4, p. 358) the following numbers for the wives in Edinburgh and Glasgow, *taken as a whole* :—

Age	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Fecundity	50	41·8	34·6	26·6	20·4	8	1·3

The two last numbers are probably not so accurate as the others—one from vague statements as to "forty years of age;" the other on account of some omissions noticed in a footnote to the table. As, unfortunately, we cannot get data for each year separately, we can only test the above formula for intervals of five years. The numbers just given may therefore be taken as *proportional* to f_{17}, f_{22}, f_{27}, f_{32}, f_{37}, f_{42}, and f_{47} respectively.

4. We may now construct the second line of the following table, according to the formula above, by adding to the number for any quinquennial period all those which follow it:—

Age	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Fertility	182·7	132·7	90·9	56·3	29·7	9·3	1·3
F_t	12	8·9	6	3·7	2	0·6	0·1

The numbers in the last line are proportional to those in the second, on the assumption that a woman of 15–19 will have a family of twelve.

Dr DUNCAN quotes (*Trans. R. S. E.*, 1865–6, p. 302) from the Journal of the Statistical Society the following table of values of F_t for the mass of married women in the district of St George's-in-the-East. This is, unfortunately, not quite comparable with the last, as the quinquenniads differ by one year of age; and, besides, the ages at marriage differ in the different columns. But there seems to be no attainable table so nearly approaching what we require for comparison.

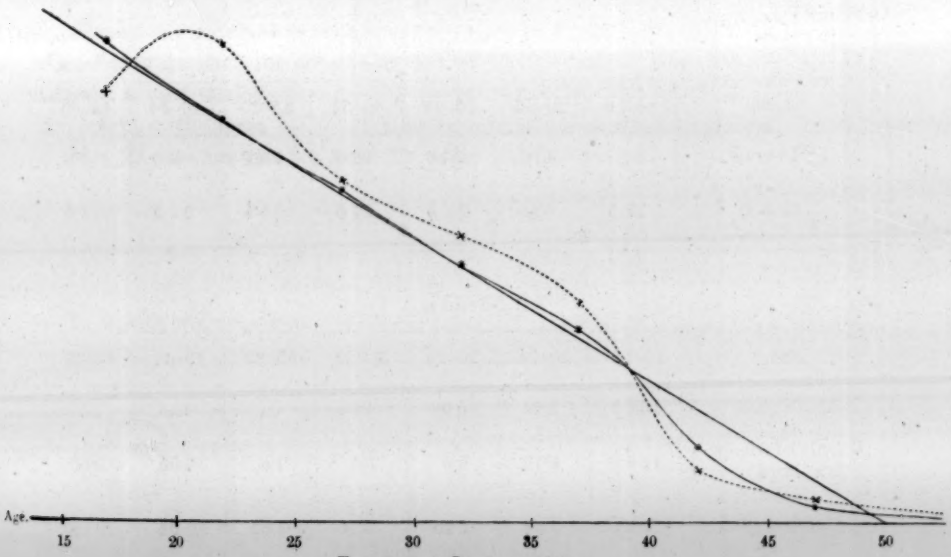
Age.	16–20	21–15	26–30	31–35
F_t	10·85	8·24	5·00	4·00

Neglecting the difference of the quinquenniads in the two tables, and taking 11 instead of 12, for the sake of direct comparison, as the value of F at 15–19 in the first, we have—

Calculated	11	8·16	5·5	3·4	1·9	0·55
Observed	10·85	8·24	5·0	4·0	...	...

These numbers agree as well as could possibly be expected.

5. If we project the numbers above given for $f_{17} \ldots f_{47}$, and try to represent the values of f for all ages by the ordinates of a curve, whose abscissæ denote the corresponding ages, we have the continuous curve of the following diagram :—



FECUNDITY AT DIFFERENT AGES.

The continuous curve is founded on Edinburgh and Glasgow Tables. The dotted curve on Tables of Sterility. The straight line from the formula $k\,(50-t)$.

The straight line, which almost coincides with the continuous curve—at least from the age of 17 to that of 40—and whose departure from it above that age must depend to some extent on the defects of the table pointed out in § 3, intersects the axis at 50. We may obviously assume it as very nearly representing the tables. And we can therefore express the value of f_t by a number proportional to $50-t$. Thus—

$$f_t = k(50 - t)$$

(where k is a *number*, whose value we can easily find), is a simple formula very closely representing the tabulated results.

6. But F_t can now be represented in a form almost as simple. For—

$$F_t = f_t + f_{t+1} + \ldots\ldots + f_{49}$$
$$= k\left\{(50-t) + (49-t) + \ldots\ldots + 1\right\} = \tfrac{1}{2}k(50-t)(51-t)$$
$$= \tfrac{1}{2}k(50-t)^2, \text{ nearly enough for our purpose.}$$

7. Thus it appears that—

Fecundity is proportional to the number of years a woman's age is under fifty; and

Fertility at that age is proportional to the square of the same number.

8. To show, numerically, how closely these formulæ represent the tables is of course easy.

Fecundity.

Age	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Dr Duncan	50·0	41·8	34·6	26·6	20·4	8·0	1·3
$\frac{3}{2}(50-t)$	49·5	42·0	34·5	27·0	19·5	12·0	4·5

Fertility.

Age	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Dr Duncan	10·85	8·24	5·00	4·00	...	...	...
Calculated from f_t as in (4)	11·0	8·16	5·5	3·4	1·9	0·55	0·09
$\frac{1}{10}(50-t)^2$	10·89	7·84	5·29	3·24	1·69	0·64	0·09

9. *Example.*—As an application of the formula, let us suppose a woman, who was married ten years ago at the age of twenty, to have now five children :—

At marriage . . . . . $F_{20} = \frac{1}{2}k(50-20)^2 = 450\,k$
At present . . . . . $F_{30} = \frac{1}{2}k(50-30)^2 = 200\,k$

But the difference $F_{20} - F_{30}$, or $250\,k$, represents five children. Hence F_{30}, or $200\,k$, represents four more. So that her family will probably amount to nine.

10. As illustrating the subject farther, I append portions of another of Dr Duncan's tables (*Trans. R. S. E.*, 1865–6, p. 306), with formulæ for comparison founded on the type $f_t = k(C - t)$.

Fecundity.

Age at Marriage.		Age 20–24	Age 25–29	Age 30–34	Age 35–39	Age 40–44	Age 45–49
15–19							
	Table . . .	64·1	52·1	36·2	19·6	2·4	...
	3 (43—age) .	63·0	48·0	33·0	18·0	3·0	...
20–24							
	Table . . .	...	61·7	41·7	24·5	11·4	0·3
	3 (46—age) .	...	57·0	42·0	27·0	12·0	0·0
25–29							
	Table . . .	...	...	40·6	28·2	9·1	1·3
	2·66 (47·5—age)	...	...	41·4	28·0	14·7	1·4
30–34							
	Table . . .	...	...	...	34·0	19·2	4·5
	3 (48·5—age) .	...	...	...	34·5	19·5	4·5

These formulæ seem to represent the tables pretty closely—with the exception of a solitary number for those married at 25–29—and if they may be trusted, indicate a very curious result. Of course, when the fecundity is given by an expression of the form $k\ (C - t)$, C is the age at which sterility arrives.

Now, it appears that we have for wives married at

	Fecundity.
15–19	k (43—age)
20–24	k (46—age)
25–29	k (47·5— age)
30–34	k (48·5—age)

In words, *the advent of sterility is hastened by early marriage.*

Thus sterility occurs according to the following table:—

Age at Marriage.	Age of Sterility.
15–19	43
20–24	46
25–29	47·5
30–34	48·5

This is singular enough, and seems to be well borne out by the tables, since the age of sterility is *uniformly* later as the age of marriage is greater. But, of course, far more extensive observations must be made and discussed before such a point as this can be settled.

Accepting it, however, for the present, we may calculate from the last table, and the table of fecundity already given, the whole fertility as depending on the age at marriage. For, if t be the age at marriage, C_t the corresponding age of sterility—

$$\text{Whole fertility} = \tfrac{1}{2}\ k\ (C_t - t)^2.$$

In this formula k is to be found. But we have

$$\text{Fecundity at marriage} = f_t = k\ (C_t - t).$$
$$\text{Hence, whole fertility} = \tfrac{1}{2}\ f_t\ (C_t - t).$$

If we accept 10 children as representing the whole fertility at 15–19, which seems a reasonable assumption, we have

$$10 = \tfrac{1}{2} f_{17} (43 - 17) = 13 f_{17}.$$

Hence $f_{17} = \frac{10}{13}$, from which (by proportion) the other values of f are easily found. Hence—

Age at Marriage.	Whole Fertility.	Ft.
15–19	10·0	10·0
20–24	7·7	7·4
25–26	5·5	5·0
30–34	3·4	3·1

The last column has been added for comparison, so as to show how the later advent of sterility in the more advanced marriages increases the fertility.

It may be well to notice that the interpretation of the expression $f_{17} = \frac{10}{13}$ is, that *a wife of* 15–19 *will, on the average, become pregnant at* 1·3 *years after marriage*, that is, she will have a child within about two years of marriage. This limit of time depends, however, on our assumption of 10 children as the measure of the fertility at 15–19, and childless marriages are included in the data. Dr DUNCAN gives (*Trans. R. S. E.*, 1865–6, p. 297) 1·52 years as the average interval between marriage and the birth of the first child. The reason of the discrepancy is of course this, that in our calculation the mass of wives is considered, and in Dr DUNCAN'S only fruitful marriages are taken account of.

II. *Fecundity and Fertility of the Average Individual.*

11. If we endeavour to derive formulæ of a similar character from the tables of sterility, the results are not quite so simple. Thus we find (*Trans. R. S. E.*, 1865–6, p. 319)—

Age at Marriage	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Percentage Sterile .	7·3	0	27·7	37·5	53·2	90·9	95·6
Percentage not Sterile	92·7	100	72·3	62·5	46·8	9·1	4·4

From the manner in which this table was formed, it would appear that we are justified in taking the numbers in the last line as proportional to the average fecundity at the respective ages. But the curve representing these numbers differs considerably more from a straight line than that derived from the other tables. It is the dotted curve in the figure. It is true that if we consider the loose way in which women from 30 to 40 call themselves 30, and those from

40 to 50 call themselves 40, we might expect the smaller ordinates belonging to higher ages to be pushed back, as it were, towards 30 and 40, thereby apparently accounting for the two depressions which appear in the curve about those ages. That this is no fancied explanation may be gathered from the following scandalous facts recorded in the Census Report of 1851, p. xxiv.:—

In 1841 the number of girls, of ages 10–15 was . . .	1,003,119
But in 1851 these had become young women aged 20–25, and numbered .	1,030,456

This number, when corrected from the tables of mortality, obviously includes about 140,000 women whose ages had increased by less than 10 in ten years!

Again, in 1841 the number of women aged 20–25 was . . .	973,696
But in 1851 those who had reached 30–35 were only . . .	768,711

indicating at first sight a fearful death-rate, but really showing how strong is the desire to be considered as remaining under the magic limit of thirty years of age.

To complete the examination, however, let us see how far these data from sterility agree with the formula deduced by the other processes.

Fecundity.

Age.	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Percentage not Sterile,	92·7	100	72·3	62·5	46·8	9·1	4·4
$3\frac{3}{7}(50-\text{age})$	113·1	96	78·9	61·8	44·5	27·4	10·4

It is easy, of course, to construct a formula to represent any series of numbers, but unless it be simple it is of little use; and the approximation we have got seems close enough, if we remember the almost certain deficiencies in the numbers for the two highest ages, and the immaturity, &c., which may easily be supposed to account for that at 15–19. But there is another cause which may serve to account for part of the discrepancy, as in fact Dr DUNCAN's table shows. This is that plural births are not eliminated. In fact, at age 20–24 there are a good many more children per annum than mothers in his table, which thus virtually assumes that no woman of 20–24 is sterile. This accounts for the great rise in the (dotted) curve at the age of 22.

By the process of § 3 we form the first line of the following table. The second is formed on the type $F_t = \frac{1}{2} k\ (50-t)^2$.

Fertility.

Age.	15–19	20–24	25–29	30–34	35–39	40–44	45–49
F_t from f_t observed,	387·8	295·1	195·1	120·8	60·3	13·5	4·4
$\frac{19}{50}(50-t)^2$	414	298	202	123	64	24	4

This coincidence also is close enough, and would be still closer if we had the numbers for f_{50} and upwards, as the smaller numbers in the table, where the deficiency lies, would thus be increased proportionally much more than the larger ones.

III. *Relative Fertility of Different Races.*

12. We may apply the above results to compare the fertility of different races—a problem of considerable interest. We shall not attempt a rigorous solution, for the application of which, indeed, we have no sufficient data; but shall make one or two postulates, which will probably be easily admitted, and which will enable us to avoid complication.

13. Suppose that for ten or fifteen years we may consider the number of marriages at any given age to remain practically unaltered, we may then consider *the births in any one year as represented by the total fertility of those married in that year*. That is, the children born in that year of mothers married at 30–34, for instance, are due to those married last year, the year before last, and so on for fifteen years back, at the age of 30–34; and as the number is supposed nearly constant for some years, we have the fertility of *all* for one year (very nearly) by calculating the total fertility for the rest of their lives of those married in that year. As population, and with it the number of marriages, is generally increasing, this process will slightly exaggerate the numbers sought; but, in *comparing* two growing countries, such as England and Scotland, no perceptible error will be introduced.

14. We next assume that the *law of fertility as depending on age is the same in the two countries compared*. That is, we assume that

$$\frac{F'_t}{F_t} = \frac{F'_{t+1}}{F_{t+1}} = \frac{F'_{t+2}}{F_{t+2}} = \text{etc.}, = e,$$

where e is some definite number; and F_t, F'_t represent the fertility in the two races at age t.

This will evidently be the case if the fertility be really expressible, as above, in the form

$$F_t = \tfrac{1}{2} k (50 - t)^2,$$

for two such expressions can only differ through the number k; unless indeed the age at which sterility comes on, here represented by 50, should happen to be greatly different for different races. On this point we have no information.

15. Let, then, μ_t be the number of marriages of women at t years of age in any one year, β the number of legitimate births in a year, we have by the above postulates

$$\beta = \Sigma \mu F = \mu_{15} F_{15} + \mu_{16} F_{16} + \ldots + \mu_{49} F_{49}.$$

For another country

$$\beta' = \Sigma\mu' F' = e\,\Sigma\mu' F,$$

where e is the ratio of the fertility of the second race to that of the first. These equations give

$$e = \frac{\beta'}{\beta} \cdot \frac{\Sigma\mu F}{\Sigma\mu' F}$$

where the *absolute* fertility of either country is no longer involved, so that we may employ for the values of F the expressions in § 4, or those in § 8.

16. *Example.*—From the Registrar Generals' Reports for England and Scotland last published, we extract the following data :—

	England, 1864.	Scotland, 1862.
No. of Marriages, .	180,387	20,597
Legitimate Births, .	692,827	96,693

Percentage of marriages of women in 1862 at the ages—

	15–20	20–25	25–30	30–35	35–40	40–45	45–50
England, . .	13·60	49·74	19·55	7·28	3·89	2·67	1·57
Scotland, . .	13·07	46·28	24·13	8·54	4·36	2·03	0·95
And we assume, in accordance with §§ 4 and 8—							
F proportional to .	12·0	8·9	6·0	3·7	2·0	0·6	0.1

$$\text{This gives } \Sigma\mu F = \frac{20{,}597}{100}[12 \times 13{\cdot}07 + 8{\cdot}9 \times 46{\cdot}28 + \ldots]$$

$$= 20{,}597 \times 7{\cdot}55 \text{ for Scotland.}$$

$$\text{Also } \Sigma\mu' F = 180{,}387 \times 7{\cdot}595 \text{ for England.}$$

$$\text{Hence } e = \frac{692{,}827}{96{,}693} \cdot \frac{20{,}597}{180{,}387} \cdot \frac{7{\cdot}55}{7{\cdot}595} = 0{\cdot}812 \text{ nearly.}$$

A more accurate comparison would be obtained by employing the average number of marriages at various ages for five or ten consecutive years, instead of those in any one year, as above, which are liable to considerable fluctuations. But we have not data enough. It would appear, then, that *the absolute fertility of the mass of married women in England is only about* 80 *per cent. of that in Scotland.*

That the fertility is less in England than in Scotland has been shown by the Registrar-General for Scotland (*Report* 1866). But he makes the ratio considerably greater than the preceding estimate.

It is to be observed that if the insinuations we sometimes hear about

Scottish marriages have any foundation in fact, their consideration would tend to make the difference in fertility between the two countries even greater than that just given; for legitimation *per subsequens matrimonium* does not put a child's name on the Registrar's books.

17. The fact that in England and Scotland the quantities $\Sigma\mu F'$ and $\Sigma\mu F$ are almost exactly proportional to the number of marriages in the two countries, shows that, although Scottish women, as a rule, marry later in life than English women, the long period (25–40) during which their marriage-rate exceeds that in England, as compared with the shorter period (20–25), during which it falls behind, almost makes up for the diminished fertility at the more advanced age.

18. It only remains to construct the values of the quantities F_t for each country, taken, of course, from the mass of the wives.

As before (§ 15), we should have had

$$\beta = \Sigma\mu F$$

if we had used proper absolute values of F. But we used the numbers 12, 8·9, 6, &c., which are obviously too large. Reducing them all in the ratio ϵ to 1, and substituting for β, &c., their values, we get

$$96{,}693 = 20{,}597 \times 7{\cdot}55\ \epsilon.$$

This gives

$$\epsilon = 0{\cdot}622.$$

from which we construct the following table of

Fertility of the Mass of Wives.

	15–19	20–24	25–29	30–34	35–39	40–44	45–49
Scotland, ...	7·44	5·54	3·77	2·30	1·24	0·37	0·06
England, ...	6·04	4·49	3·02	1 87	1·01	0·30	0·05

19. In conclusion, it may merely be repeated that we have attempted no elaborate or exact inquiry into this question; indeed the utter insufficiency of data would have rendered such a proceeding absurd; and we have, for the same reason, abstained from employing some of our own results, such as those of § 10, in modifying the earlier ones, by the help of which they have been arrived at. Thus, for instance, we should be led by the results of § 10 to use in the formulæ of §§ 5, 6, a number somewhat less than 50, as corresponding to the average age of sterility. As in all questions of average, the value of our deductions in this matter is mainly dependent on the extent and accuracy of our data, and it is sad to think that the enormous blue-books which load our shelves contain so much painfully-elaborated information which is of no use, and so little of those precious statistics which would at once be easy of acquirement and invaluable to physiologists.

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